PETROLEUM DEVELOPMENT AND TECHNOLOGY 1939

PETROLEUM DIVISION

A. I. M. E.

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PLANS OF THE PETROLEUM DIVISION FOR 1939–1940

The aim and ambition of the Petroleum Division, its officers and committees, is so to serve the members that they may profit most from its functions. The facilities of the Division were greatly expanded during 1938 and the additional contacts now available through the office of the Assistant Secretary and service through the quarterly publication of PETROLEUM TECHNOLOGY make it no longer necessary to await the Fall or February meeting for the presentation of new ideas or the description of advanced technique. Members are urged to contribute papers at any time during the year instead of just before one of the meetings, and an early editing and publication of the acceptable material are assured.

It is planned to have the Assistant Secretary travel considerably, visiting the various centers of petroleum activity, and to bring the members, particularly the student groups, into closer contact with the Institute. Such travel will also enable the Institute staff to know more about the needs of the Division. Periodical surveys of this character will assist in determining how, or how better, to serve the members.

But with the additional activities of the Division come additional obligations. Through the help of the present membership, it is planned that the many who now avail themselves of the Institute's reference works be brought closer by direct membership. Many petroleum engineers and technologists remain outside of the Division simply because they have not been asked to join. It is planned to increase the membership, not because importance is placed in a larger number, but simply because with an increased membership it becomes possible to serve all members better. Each present member should extend an invitation to his friends and qualified acquaintances or send their names to the Membership Committee.

The Fall and February technical meetings, which have been so successful in the past, will be continued during 1939–1940. One meeting is to be held at Galveston on Oct. 4, 5 and 6; one at Los Angeles on Oct. 19 and 20, the general meeting at New York during February 1940. The dates are arranged so that those who desire to do so can attend them all.

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Chapter I. Production Engineering

Mud Technique in Iran

By M. W. Strong*

(New York Meeting, February, 1939)

The technique of handling drilling muds varies somewhat, partly because of personal factors but mainly because of differences in formation, the type of problems, and the general drilling conditions in different localities.

The much greater depths to which bore holes are now carried have made necessary closer attention to and great modifications of all aspects of drilling-mud technique. Increased depth means smaller hole, smaller drill pipe, smaller clearances, higher pumping pressures, higher differential pressures between shows and the mud column, less accurate control of the weight of the mud column, delayed receipt of formation data, and poorer samples. It means longer delays and greater hazards in rectifying mistakes or dealing with accidental occurrences. Equipment on a larger scale is necessary and more pains must be taken with layout. Lastly, the budget costs of raw materials have risen to high figures and economy of time and of direct monetary expenditure have come to mean much more than formerly.

A mud laboratory is now part of the essential establishment of a modern oil field and to it current problems can be submitted for the most thorough investigation. The detailed chemical properties of all materials purchased or quarried have to be investigated. Detailed data on the physical properties have to be ascertained and research on improvement of material and its most efficient use has to be carried out.

In this paper will be discussed the main mud problems of Iran, some of which are peculiar to local conditions while others are of the general type common to all workers in this subject.

Underground Conditions

In deep wells in Iran the normal overburden may consist of: (1) up to several thousand feet of marls with interbedded sandstones and limestones of varying porosity and permeability; (2) beneath this a chemical series of rock salt and anhydrites, containing various marls and thin limestones,

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of which the drilled thickness varies from over 10,000 ft. to less than 300 ft.; (3) underlying thick limestones with rare thin marl bands.

The top series (1) sometimes contains high-pressure oil or gas shows in the sandstones, but more often only low-pressure waters. Where both are present in the series, considerable difficulties ensue because the heavy muds tend to form filter cakes on the low-pressure sandstones.

In the lower part of the second series (2) is a group of hard and soft marls and limestones containing waters high in magnesium chloride content. Gas may also be present and the rock pressures range from 0.75 to nearly 1 lb. per sq. in. per foot of depth, thus calling for the use of very heavy muds.

A peculiarity of these particular waters is their small but continuous flow, suggesting that they are contained in plastic beds of low permeability, under strain, and that, under reduction of pressure in the neighborhood of the well the waters are slowly extruded from the strata. Their mode of formation suggests that these marls were covered, over a very wide area, by impermeable chemical deposits, with the result that they could never get rid of their waters by extrusion under normal compaction conditions and so are supersaturated at the pressures to which they have afterwards been subjected.

A further complication of this chemical series often arises, due to violent displacements. Extreme folding, faulting and thrusting, with cutouts and duplication, is characteristic of the series. These features contribute to drilling difficulties, owing to the instability of the wall of the hole in the neighborhood of the faults and thrusts, and at depths over 8000 ft. such places are formidable obstacles.

Throughout the salt series it is necessary to drill with saturated brines to avoid accentuating difficulties by leaching out salt and causing the marls to cave.

The lower series (3) of limestones is competent. The pressures may be 1000 lb. or so below those of the chemical beds and if the lower pressure conditions are penetrated while the mud pressures and gravity are for high-pressure conditions, the stage is set for a fishing job with frozen tools.

Within the limestones themselves, fissuring, fracturing and permeable beds provide the main difficulties, and special methods have been developed to deal with them.

Routine Records of Mud Operations

In order to make readily available the data respecting mud operations in wells, more especially in deep wells, the essential information is entered daily on a graphic log of which Fig. 1 shows the main features. On this form are entered the following details: (1) weight as recorded on the rig; (2) weight as recorded in the laboratory from samples sent

in daily; (3) Marsh funnel viscosity (or other suitable units); (4) mud losses to formation; (5) pumping pressures, average and maximum; (6) pumping speeds (in deep wells); (7) remarks on general drilling conditions, additions to mud, such as bentonite, brine or barite, shows, formation changes, and the like; (8) size of hole, size and type of drill pipe and casing; (9) salinity of mud, where necessary. Vertical columns represent days, against which the depth is entered.

For normal wells—i.e., wells in which no unusual features or particular difficulties occur—such charts are not necessary, but for deep tests or for

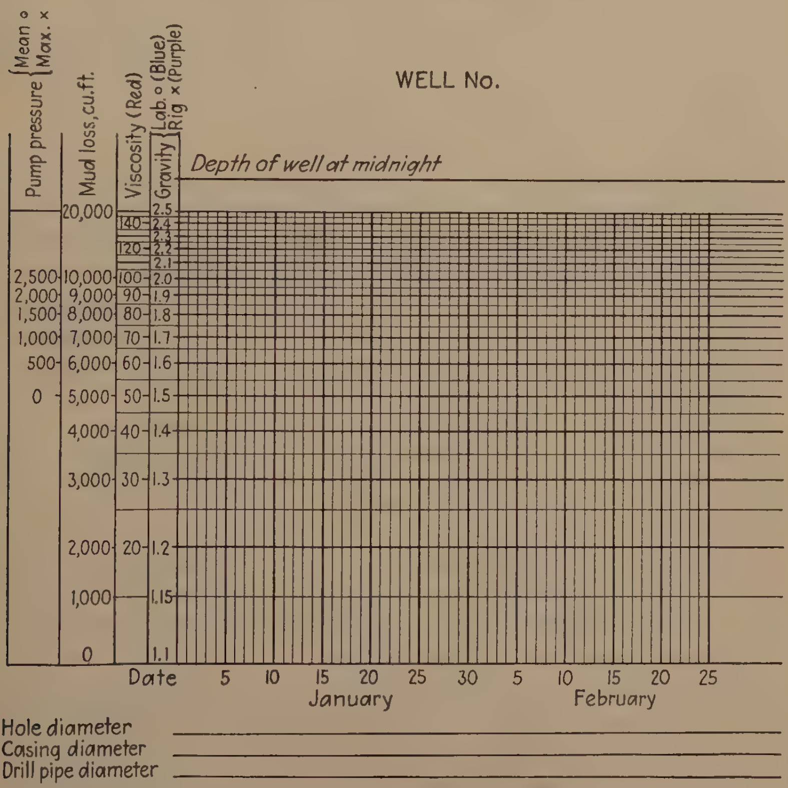

FIG. 1.—CHART FOR MUD LOG.

wells drilling in difficult formation, such graphic mud logs are of considerable value, both for watching the trend of events and foreseeing necessary measures and for forecasting general mud requirements in contemplated new tests.

ROTARY MUD SAMPLING

In dealing with mud problems in wells, it is of the utmost importance to have accurate knowledge of the types of strata penetrated, their thickness and depth, the position of faults, and other information, so that

it will not be out of place to mention here our standard rotary mud sampling technique. When no particular difficulties are envisaged, the mud is kept thick enough to ensure accurate rotary mud samples from 1 to 2-ft. intervals (collected from a vibrating screen). By this means, almost perfect logging is possible to something over 6000 ft., though beyond that depth several factors may tend to more admixture of samples. Average muds under these conditions run from 1.2 to 1.4 specific gravity.

In Iran, markers are often few and thin, and by this means it is usual to get adequate returns of beds as thin as a fraction of an inch. It has been found that much time is saved and accuracy achieved by close rotary flush sampling, using sufficiently thick mud.

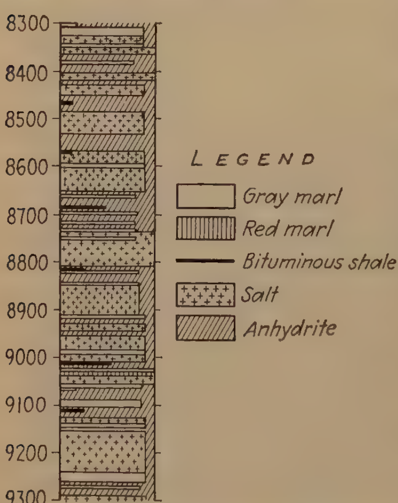

FIG. 2.—PART OF GRAPHIC LOG OBTAINED FROM ROTARY FLUSH SAMPLES.

Fig. 2 shows a portion of a log between 8300 and 9300 ft. using flush samples taken from the screen at 2-ft. intervals. It shows the routine graphic log entries of percentages of rock types and indicates that the mixture of different materials, due to lag, is small. In thick limestones this method of sampling makes simple the separation of lithological types showing but slight differences of color or texture.

CORING

Coring, for purposes other than dip evidence or special research specimens, is now practically discontinued, even in the most complicated tectonic conditions of faulting, overfolding and repetition.

Coring was found valuable recently in checking a certain zone where flush samples showed great admixture; the core proving a complicated fault breccia of heterogeneous material.

CURRENT PROBLEMS

The main problems are:

1. High-pressure shows, necessitating very heavy muds.

2. Porous or permeable formations, necessitating the use of bentonite to stop mud-ringing.

3. Caving formation, due either to tectonic causes, as in heavily fractured zones, to beds plastic under high rock pressure, or to beds taking up water from the mud and sloughing into the hole.

4. Highly fissured formations, causing lost circulation and necessitating special temporary measures.

The pure mud problems, which have to be solved in connection with the above, are:

1. The heaviest muds usable under given conditions.
2. The least permeable or non-mud-ringing muds obtainable, fulfilling also other necessary requirements.
3. The most satisfactory setting or sealing mixtures.

(Loss or sealing-off of production is being satisfactorily dealt with either by drilling in with water, in suitable conditions, or by subsequent acid treatment if mud has been used. As the pay is a limestone and the raw muds are high in lime content, this presents no great difficulty.)

Heavy Muds

As a weighting material barite is used mixed with a water-bentonite base. If the strata to be drilled contain neither salt nor salt water, a 1.05 sp. gr. bentonite is usually of sufficient strength, but if brine conditions have to be met, the bentonite is preferably hydrated as much as possible by pumping through high-pressure nozzles with fresh water before introducing the brine. In this way much greater suspension efficiency is obtained from the bentonite.

Where no fresh water is available, the bentonite may have to be mixed in concentrations approaching 9 lb. per cubic foot. This is admittedly rather inefficient, but improved methods are being studied.

When muds of 2.5 sp. gr. or over are needed, magnesium chloride saturated brine is used as a base, so as to reduce the viscosity.

For moderate muds, lime marl is useful in small concentrations as a suspending agent, owing to certain reactions between it and the $MgCl_2$, which impart a slimy lubricating property to the grains and also counteract to some extent excessive settling or packing.

The heaviest muds we have been called upon to pump down wells was 2.76 sp. gr., which went down 6000 ft. of 4-in. drill pipe without trouble.

When drilling into beds with high-pressure shows, it is convenient to do so with a bottom-hole excess differential pressure not exceeding 100 lb. per sq. in. If there is good connection, subsequent production is not usually difficult.

Filter Cakes and Permeable Beds

To reduce the growth of mud sheaths, muds must be as nonpermeable as possible. If thin, they should not settle and if on porous surfaces they should form either the thinnest possible nonpermeable mud sheath or, if a thick sheath, then a soft one of low rigidity and having lubricating properties such as those formed by good bentonites.

In deep wells the drag due to mud sheaths is a constant source of danger and the utmost precautions are taken to avoid it. Bentonite is used liberally and amply repays any expense upon it. Even in brine mud conditions, bentonites still retain the property of nonpermeability and lubrication.

The natural hazards are sometimes formidable, as the following two, not unusual, conditions will illustrate:

1. A well has reached a high-pressure show that calls for a 4000-lb. bottom-hole pressure to kill it. The casing has to be set just above a porous bed 1000 to 2000 ft. lower down, which puts up only a 3000-lb. bottom-hole pressure. This calls for very careful preparation of the mud to ensure safety if the lower bed is penetrated, and close sampling, to stop drilling for setting casing, within a narrow range of from 5 to 10 ft. necessitated by the formations. Faulting is a normal hazard and the most accurate sampling does not do away with the necessity of having the mud in a condition to fulfill its function until sufficient data are at hand to suspend drilling.

2. The other instance is penetration of 1000 ft. or so of porous and permeable formation that is either gas or oil bearing.

If heavy mud has to be used to control the upper shows, the increasing differential pressure with depth means an increasing tendency to mud-ringing. This condition has also been met successfully by the use of ample bentonite.

Very heavy muds (i.e., over 2.0 sp. gr.), however, mean a certain amount of unavoidable thickness, in which case scouring of mud sheaths using high pumping speeds cannot be employed.

In one well where pressures were low, and 2000 ft. of continuous fractured and porous formation caused severe mud-ringing, a natural mud was finally found which was stable at 1.1 sp. gr. when mixed with sea water—the only water available. This was pumped at high speed and scoured off the thinner part of the rings leaving only a thin cake of low permeability on the wall of the hole, which was then kept clean enough for drilling to proceed.

If the mud is too thick as well as too heavy the hole becomes "dirty" as very small fluid losses mean the formation of much very thick rather sticky mud on the wall so that a happy mean has to be sought between the various extremes.

Lost Circulation

Lost circulation is fairly common in fissured limestones.

In normal conditions where the fissures are not large an effective method is to pump down thick mud full of cuttings.

In more stubborn cases mud and cement mixtures are used with effect, the mix being as thick as possible.

In semicavernous conditions we have used sand, cement, chopped rope, bentonite and small desert bushes, mixed together on the derrick floor and made up by hand into thick plastic lumps, inserted by hand into the casing on top of a plug, and finally pumped to the spot in 100-cu. ft. batches, leaving some in the hole and some in the cavern. Each batch was allowed to set for 24 hr. before drilling through. Several lots of these "caverns" were met but all were successfully treated by this method, in which the proportion of cement used was 1 drum of cement to 5 drums of sand.

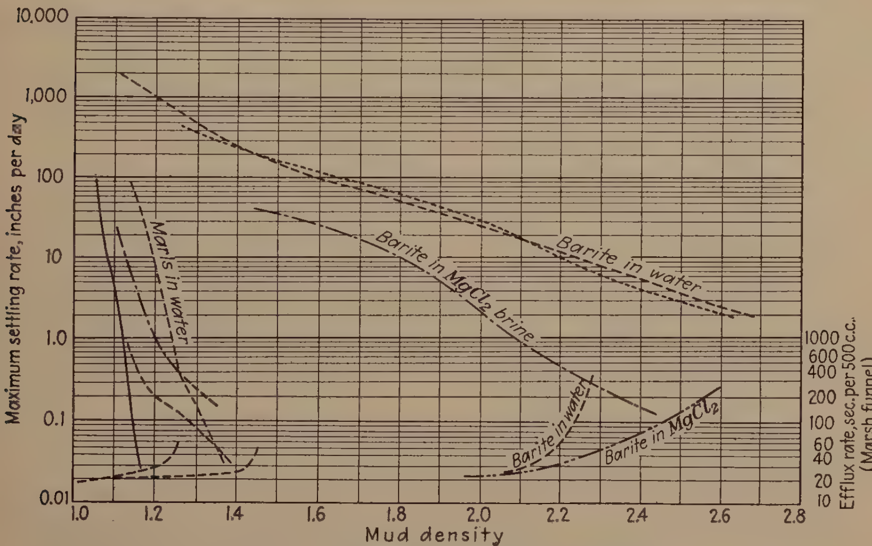

FIG. 3.—VISCOSITY AND SETTLING CURVES.
The upper curves sloping down from left to right are settling rates against density. They represent samples of barite and mud from different sources. The curves sloping upward from left to right represent efflux rates against density for Marsh funnel, 500 c.c. in and 500 c.c. out.

LABORATORY WORK

In the laboratory the work is divided roughly into routine and research.

Routine

This comprises the chemical and physical examination of all mud materials contemplated for use, such as commercial materials or materials quarried locally. This necessarily involves the recording of the various properties in such a manner that easy comparison is possible, quantitative results being aimed at.

The properties examined necessarily vary somewhat with the drilling conditions. For normal shallow wells, sedimentation curves and Marsh funnel viscosities are often sufficient criteria of suitability and we attach a chart, Fig. 3, which we have found useful for presentation of these data.

For deep wells bentonite mixtures have to be examined for efficacy in saline waters, as we have found that various bentonites on the market differ considerably in their stability in brines and it does not follow that a bentonite that is most stable in a dilute brine will be most stable in a concentrated brine.

For the examination of mud-ringing properties, both the filter press and the centrifuge are employed, the degree of compaction, either under filtering conditions or high gravities providing valuable checks on the thickness and hardness of the rings to be expected in given conditions.

Finally, after due investigation of the problem in a particular well, it is the function of the laboratory to furnish an exact specification of the materials and their proportions which the laboratory recommends for employment. The drilling department is constantly consulted on all details, and the final mud used necessarily has its approval.

Research

This branch of the laboratory's activities has less bearing on direct drilling requirements and deals more with fundamental problems with a view to the general improvement of the muds in use, increasing the flexibility of control of special properties, and foreseeing and forestalling future problems and requirements.

As a first step in this direction, standardization of measurement of mud properties is receiving constant attention.

Sedimentation and Allied Processes.—Sedimentation has already been briefly mentioned. Closely allied to it are compaction and permeability. But whereas in pure sedimentation (without coagulation) intermolecular and surface-tension forces can generally be neglected, they will obviously have a determining effect on both the latter properties.

A point of interest here is the tendency of certain clays or marls to cave or swell into the hole. The conditions are not clearly understood. The sediment may have been over-compacted by earth strains and so take up water at the wall of the hole with consequent sloughing, or it may have water which has been imprisoned and which is in excess, at the pressures to which it is subjected, and so swell into the hole when drilling reduces the local pressure.

It is found that certain sediments when compacted in a centrifuge will swell again to a greater volume on reduction to normal gravitational forces. Which causes are active in wells will no doubt be decided by the drilling technique that is found to counteract the difficulty.

Surface Tension.—Surface tension is a problem that affects the preparation of heavy muds and the subsequent elimination of air or gas. These are troublesome factors in very high-pressure wells, especially with barite-brine solutions.

Free fall and splashing of the fluid at any part of the circuit is cut out as far as possible and the cleaning of the mud is usually done by jetting with a mud gun, although vacuum methods were found very effective in one difficult case.

Centrifugal methods are being experimented with.

Surface tension also constitutes a problem in salvaging brine-shale-barite muds and no method is known to us by which the barite may be separated out again from such mixtures—even by centrifuge.

At present the recommended procedure is not to throw the mud away when too thick but to keep it for use in some other well where a mud of lower gravity is required.

An interesting experiment in surface tension is the following: Make up a thin mix of clay and oil, which will flow readily in small receptacles. On sprinkling a small quantity of water on to this and mixing, the fluid will rapidly turn into a crumbly mass, which can be sprinkled on the floor like moist sand. On further addition and mixture of water, an extremely stiff, doughlike mass is formed. Additional water sets up a greasy consistency and oil drops begin to separate out. Further additions of water soften the grease and set free more oil, until there is a fairly soft mud with much free oil. When the process is continued, the mud gets thin enough to take up the oil, which disappears into the mud again in the form of an emulsion.

This experiment throws some light on the process of the sealing off of oil sands, especially if muddy, by water muds. The process of sealing off minor fissures and coarse, porous beds by the employment of hydrophilic materials inserted into the fissures in the form of oil mixes, and subsequently followed by water muds, can be readily appreciated after seeing this experiment.

Viscometry.—Although as a rough guide of mud quality the Marsh funnel is extremely convenient, more precise measures of viscosity are rapidly becoming necessary.

It would appear that the concentric cylinder viscometer must eventually find a place in all mud laboratories. Such instruments show clearly the essential elements of thixotropy.

Experimental work to date indicates that if a mud is sheared at a steady rate indefinitely, and below the rate at which turbulence sets in, it finally takes up steady values for rigidity and viscosity for that rate of shear.

On changing to a higher or lower rate of shear, new equilibrium values for the rigidity and viscosity at this new rate of shear are established.

In practice, considerable time may be necessary with bentonite muds to establish stable values for each rate of shear, and the way in which the values change during the passage from one stable state to another are not yet known, the hysteresis effects being complicated.

The important point in practice is to provide a laboratory method for estimating static and dynamic frictions of heavy thixotropic muds in deep holes where pumping pressures are unavoidably high, and for this purpose we have made a concentric cylinder viscometer capable of a very wide range of shearing speeds.

Mechanism of Sealing Fissures.—It has been found in the laboratory that, in order to obtain a mud seal in a fissure of given cross section the mud must have a certain thickness; otherwise it flows freely through the fissure. When once the thickness exceeds a certain value, the differential pressure induced at the entrance of the fissure leads to expression of water and rapid increase in the thickness of the mud. In this way a plug is formed at the fissure entrance, and upon the plug's surface additional pressures merely cause the building up of a larger filter cake.

A small back pressure usually suffices to remove the plug.

In practice, the consolidation of broken faulted material near the wall of the hole is best achieved by the introduction of a bentonite mud that can be forced well back into the formation and left to set.

With larger fissures the virtual size is reduced by the introduction of coarse material into the mud and forcing the whole mass back until sufficient degree of consolidation is achieved.

Emulsions.—Low-gravity drilling fluids of high viscosity are sometimes desirable, and in the laboratory we have obtained these, using oil and water.

In the presence of lime, however, these have proved unstable and further work is needed to overcome this difficulty. In beds without lime such a fluid might, however, be useful.

The emulsion may be obtained with either oil or water in suspension by adjustment of the oil cut and by chemical additions to the water.

Bottom-hole Pressure Reduction Due to Gas Cutting

It is frequently useful to estimate the loss of pressure in a mud column due to gas cutting. An approximate formula may be obtained as follows:

Let h = depth in feet,

P = pressure in atmospheres at depth h, due to mud column only.

D = hydrostatic pressure in atmospheres of a column of uncut mud 1 ft. high.

p = back pressure at well head (in atmospheres).

$\frac{n}{100}$ = percentage by volume of gas in mud at well head at back pressure p, in atmospheres.

Then the pressure δP exerted by a lamina of thickness δh at a depth of h feet is

$$\delta P = D\left(1 - \frac{np}{100(P + p)}\right)\delta h$$

Integrating between appropriate limits we obtain

$$h = \frac{1}{D}\left[P + \frac{pn}{100}\log_e \frac{P + p\left(1 - \frac{n}{100}\right)}{p\left(1 - \frac{n}{100}\right)}\right] \qquad [1]$$

or, if the well head is open and $p = 1$

$$h = \frac{1}{D}\left[P + \frac{n}{100}\log_e \frac{P + 1 - \frac{n}{100}}{1 - \frac{n}{100}}\right] \qquad [2]$$

in which the necessary values for depth, proportion of gas at the well head, and for the depth, can be substituted and the approximate loss in bottom-hole pressure calculated. The weight of the gas is of course neglected. It will be seen that, if the well head is open to the atmosphere the pressure loss at depth is very small, even for a 50 per cent cut mud at the surface; but that the total pressure loss at depth increases rapidly with increased back pressure.

DISCUSSION

(George B. Corless presiding)

H. H. Power,* Austin, Texas.—I am particularly interested in the statement made by Mr. Strong that the heaving-shale problem in Iran has caused some concern. Inasmuch as the problem is of considerable import in the Gulf Coast district at this time, I think that we should communicate with the engineers of foreign operators in order to learn of methods employed which may be applied to our local situation. I assume that the types of heaving shale in Iran are as varied as they are in the Gulf Coast district. It is evident that some attempt is made to prevent hydration of the shales and a consequent swelling of those carrying bentonites. It is also assumed that the waxy types of shales that heave, like plastic flow, are also present in Iran. A method of controlling such shales under high pressures should be ascertained in an effort to improve the present situation in hazardous areas on the Gulf Coast.

T. A. Pollard,† San Francisco, Calif.—On the Island of Bahrein recently a 1200-ft. section of very porous limestone, containing high-head salt water, was drilled without circulation. Sufficient salt water (from the same zone in another completed well) was pumped into the drilling well to keep the cuttings moving away at all times into caverns in the formations being drilled. No difficulty in drilling was experienced, as contrasted with previous prolonged and expensive attempts to maintain circulation by cement jobs, chemical mud control, and the pumping of such materials as balled cement sacks into the porous zones.

[See page 616 for author's reply.]

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Development and Production Problems in High-pressure Distillate Pools

By E. V. Foran*

(San Antonio Meeting, October, 1938)

Among the many newer disclosures that have accompanied the petroleum industry's progressively deeper exploratory drilling is the increased frequency with which the operators are encountering reservoirs of which the products at the time of discovery exist wholly or predominantly in the gas phase. The popular term "distillate pool" is most often used within the industry when referring to this type of reservoir, and in this paper the term is used in that sense. These pools have been observed in many different surroundings. In some places the entire reservoir is filled with the wet gas containing its water-white condensible products in the gas phase but apparently with no dark oil or other hydrocarbon liquids in the reservoir. The 8200-ft. horizon in the Big Lake field in West Texas is a good example of this type. At other places the wet, or distillate-bearing, gas may form a large gas cap directly overlying and in contact with an extensive reserve of dark oil. Oklahoma City, Kettleman Hills, the 8500-ft. horizon in the Big Lake field, and many others are examples of this type. There are also many places in which the wet distillate-bearing gas fills nearly the entire reservoir space, while the dark oil occupies only a narrow, bandlike zone, which marks the boundary of the reservoir along its lowest productive contour.

The heavier components of these deep pool gases are generally water white in color, a large portion of which are condensible in a conventional oil and gas separator, when operated under pressures of the order of 400 to 800 lb. per sq. in. Although the water-white products recovered in the separator sometimes have end points of 650° F. and higher on standard Engler distillation, they occur only in the gas phase in the reservoir. It is entirely possible that even some small amounts of dark colored reservoir components may occur in the gas phase when the temperature is 300° F. and pressures exceed 6000 lb. per sq. in. Close approaches to these conditions have been encountered in the deepest producing wells. The condensible content of the deep reservoir gases of the many pools that have been tested or produced to date shows a wide variation in both condensible content, per 1000 cu. ft. of gas, and physical character.

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Apparently, also, little consistent relationship exists between reservoir temperatures and pressures of the different pools. The variation in the condensible content of the reservoir gases of several pools examined by the writer indicates a spread of from 0.45 gal. per 1000 cu. ft. of gas to as high as 4.4 gal. per 1000 cu. ft. of gas. The depths at which these distillate-bearing gas reservoirs were encountered varied from 4000 to 9000 ft., and temperatures varied from 145° to 235° F.

As an example of extremes in content occurring in two reservoirs having depths of 8500 and 8000 ft., respectively, it is interesting to note that one had an initial content of 4.4 gal. per 1000 cu. ft. and the other 0.7 gal. per 1000 cu. ft. It is obvious that conditions as variable as these may present the operator with two development problems entirely unlike, each requiring a program peculiar to its own surroundings. If the figures for relative condensible content shown above as gallons per 1000 cu. ft. are expressed in terms of expected recovery per acre-foot of gas-saturated formation, it indicates, for a fully saturated sand or lime formation of 25-ft. thickness and 25 per cent porosity an expected ultimate recovery of approximately 900 bbl. per acre from the reservoir of which the content was 0.7 gal. per 1000 cu. ft., and approximately 5750 bbl. per acre for the 4.4 gal. per 1000 cu. ft. content. It is the writer's opinion that the reservoir containing the 900 bbl. per acre recoverable reserve at 8000 ft. would not justify a development program with well spacing of more than one well to 320 acres, whereas the reservoir showing a content of 5750 bbl. per acre may support a program of one well to 120 acres. The thickness of the gas-saturated sections of the deeper distillate pools has shown a range from a minimum of 15 ft. to a maximum of 400 ft., but the initial condensible contents of the gas throughout the vertical and horizontal limits of the reservoirs are remarkably uniform.

Physical Changes in the Reservoir Following Development

Although the reservoir contents of the distillate type of pool may all be in the gas phase at the time of discovery, they do not long remain so if, during development, an appreciable decline in reservoir pressure takes place. Some of the heavier hydrocarbon vapors, a large portion of which lie within the range of motor-fuel fractions, will condense or precipitate in the reservoir as the pressure is lowered, even though no change in temperature takes place. In this respect the deep high-pressure reservoirs of wet gas react to pressure decline in a manner exactly opposite to that of the shallower wet-gas reservoirs whose contents are composed of more volatile contents than the deep pools. This phenomenon is known as "retrograde condensation" and has been a subject of considerable research. The fundamental principles governing retrograde conden-

sation of hydrocarbons are covered in a report by Dr. W. N. Lacey and associates.[1]

It follows, then, that any mode of development or operation that results in a decline in the reservoir pressure will have proportionate effect on the ultimate recoveries of the condensible contents of the reservoir. The rate at which the pressure decline takes place will have no bearing on the extent of condensation within the reservoir, a slow progressive drop having the same effect as a rapid drop if the ultimate pressure change is the same in each case. While it is true that slight temperature changes within the reservoir may take place during the course of pressure decline within the reservoir, they are of no importance in their effect on condensation except possibly in the immediate vicinity of the well bore.

TABLE 1.—*Reactions through Pressure Change of* 450 *Pounds at Constant Temperature*

	Test No. 1	Test No. 2	Test No. 3
Separator pressure, lb. per sq. in.	1,725	1,500	1,275
Separator temperature, deg. F.	60	60	60
Daily rate gas flow, cu. ft.	3,430,000	3,390,000	3,450,000
Daily rate liquid recovery, bbl.	49.5	57.5	64.5
Gravity of liquid, deg. A.P.I.	68.0	68.8	70.5
Engler distillation, I.B.P.	86	76	84
	110	108	109
	129	126	124
	158	152	148
	182	178	172
	206	201	197
	230	224	220
	257	248	248
	289	276	276
	329	317	320
90	414	413	438
End point	469	461	450
Recovered	93.0	92.0	91.0
Residue	1.5	1.5	1.0
Loss	5.5	6.5	8.0

The manner in which the condensation takes place in the reservoir is a matter of interpretation, but it seems reasonable to believe that it occurs throughout the porous section of the reservoirs. It results in the wetting of the sand or lime surfaces surrounding the pores of the formation, but the quantity is too small to produce enough liquid to gravitate downward into the lower sections of the sands and concentrate there as

[1] References are at the end of the paper.

a free liquid, except in the immediate area of the well bore, where, of course, this is entirely possible. The fact that the potential liquid condensate in a sand 25 per cent porosity varies from approximately 20 bbl. per acre-foot to not over 150 bbl. per foot will serve to explain why any condensation that takes place in the reservoir other than that at the immediate well bore will not be recoverable except by methods of induced secondary saturation by means of recycling residue gas.

It may also be concluded from observations that the first products to condense in the reservoir will be composed of the heaviest components of the gas; gradually the condensate becomes higher in gravity as the pressures progressively decline. However, even the initial and heaviest condensates that form as a result of the early pressure drop in the reservoir will carry with them small amounts of the lighter fractions. This aspect of condensation in the reservoir may be partly illustrated by observing the character of retrograde condensation in high-pressure separators. This is readily accomplished by passing a well-head flow stream of constant composition through the separator and observing the results while the separator pressures are varied through a range of from 1000 to 2500 lb. per sq. in. with constant temperature at the point of separation. Table 1 shows examples of the various reactions through a pressure change of 450 lb. at constant temperature. Although the pressure drop alone resulted in an increase of more than 30 per cent in the liquid precipitation, some of the light fractions also condensed.

Production and Ultimate Recoveries

On completing a first or discovery well in one of the distillate pools, the operator is confronted with the fact that the products in the reservoir are in a single phase, the gaseous state, but at the surface become two-phase, with both gas and liquids present in the separator. If, upon limited subsequent drilling of the new pool, no dark oil is discovered, it may become necessary to study a development and operating program from a purely local viewpoint. In most cases no market outlet for gas is available, and development and production must be justified solely on the basis of income to be derived from the marketing of reservoir products that are recoverable as liquids on the surface.

When it is borne in mind that the various distillate reservoirs having an average porosity of 25 per cent and a pressure of 2500 lb. per sq. in. contain an initial reserve of from only 20 to 150 bbl. of condensible products per acre-foot, it can be readily seen that development must be restricted proportionately. The relative values of the residue gas and recoverable condensible products in the reservoir will vary greatly as among pools. Assuming the value of residue gas to be 4¢ per 1000 cu. ft., it would indicate that in practically all cases where the condensible content of the gas exceeds 1.5 gal. per 1000 cu. ft., or 36 bbl. per million

cubic feet of gas, the value of the condensible products in place or on the surface exceeds that of the residue gas. If, in the absence of a market for the residue gas, it becomes desirable to develop and operate the property, it will be necessary to return the residue gas to the same reservoir from which it came. The gas must be recycled for the sole purpose of increasing the ultimate recovery of condensible gases from the reservoir; the recycling will, of course, in no way affect the ultimate recovery of the residue or fixed gases from the reservoir.

The well-spacing program for a distillate property should be virtually the same as for the conventional "dry" gas pool, with the possible exception of one difference. A sound development program for the distillate type of pool calls for a high order of pressure maintenance by recycling the residue gas; this procedure assures a proportionately high order of sustained potential open flow for the producing wells and therefore is even better suited to a very wide spacing program than a dry gas pool.[2] For gas pools with low condensible content, it is imperative that wide spacing be adopted in order to render them commercial projects.

From the well-established fact that precipitation or condensation within the reservoir takes place as a result of pressure drop alone and in such insufficient quantities that concentration in the sands as a recoverable liquid is negligible, it is obvious that a development program of close well spacing will not increase the ultimate recovery of the condensible products of the reservoir. This fact holds true even for pools having the highest condensible content yet discovered. This same fact indicates definitely that all gases subject to retrograde condensation within the reservoir must be recovered from the reservoir in the vapor phase only.

The quantitative degree to which condensation or precipitation is now taking place within many distillate reservoirs as a result of normal pressure decline has not been observed or studied sufficiently for precise evaluation, since only one or two cases are known to the writer in which the pressure decline within the reservoir has been studied sufficiently to measure the extent of such precipitation.

Probably the best example of this type is that of the 8200-ft. horizon in the Big Lake pool, Reagan County, Texas. The initial reservoir pressure in this pool (1929) was approximately 2270 lb. per sq. in., the temperature being 173° F. The initial recovery of condensate or distillate in the separator varied from 36 to 38 bbl. per 1,000,000 cu. ft. (1.51 to 1.60 gal. per 1000 cu. ft.). This reservoir apparently contained no dark oil and no salt water, and was subnormal in initial pressure for this depth. During the development and operation of this property, a normal, slow, reservoir-pressure decline took place, and the last gas well completed in this formation was in March 1933, at which time the recoverable content in the separator varied from 28 to 30 bbl. per million

cubic feet at the reservoir pressure of 1225 lb. per sq. in. The difference in the condensible content of the gas produced from this reservoir during the past eight or nine years is due solely to the reservoir-pressure decline, which was accompanied by precipitation within the formation, all of which took place as a result of retrograde condensation, since the reservoir temperature remained constant. The gravities of the liquids recovered in the separator have shown a progressive rise from an initial of 61° to 63° gravity A.P.I. (1929) to a present gravity (1938) of from 73° to 75° A.P.I., the difference being accounted for as a result of the precipitation of the heavier components within the reservoir. The disposition of the gas from this reservoir has been in strict accordance with the highest conservation practices since it has been serving light and fuel needs during the past several years. However, the disposition of the residue gas from any reservoir of this type to extraneous points, whether on the surface or subsurface, would have no bearing on what takes place within the reservoir from which the gas is taken. Situations similar to the example given above are occurring in many other pools, from which the gas may even be used exclusively for light and fuel. In general, precipitation within the reservoirs of distillate pools during the course of pressure decline will vary with the richness of the condensible content and the amount of pressure decline. The amount, and not the rate, of pressure decline is the controlling factor in reservoir condensation. It will be recognized by all operators that a small degree of pressure decline within a gas pool is unavoidable in the ordinary course of development and operation, but the necessity for keeping the pressure decline as low as possible until the condensible products of the reservoir have been removed is of primary importance.

In all pools of the distillate type, it will be of great advantage to complete the wells with large-size casing set on top of the producing formation, and to expose as large an area as possible in the well bore, so that, for any given rate of flow the pressure gradient immediately adjacent to the well bore will be reduced to a minimum. A large-diameter casing with a large-diameter well bore will accomplish this. With this type of well completion, it is possible to deliver the gas from the reservoir to the well bore with pressure drops of only a few pounds below the shut-in reservoir and at rates of flow up to the full open-flow capacity of 2-in. tubing. This practice will reduce proportionately the amount of local precipitation around the well bore, which may take place to some extent where much of the formation has been cased off and the casing perforated. The only justification for perforating the casing would be where oil is suspected in the lower portion of the formation, and it is desirable to exclude the gas from the higher portions of the well bore. Should oil production not be developed in these places, and the well be used as a gas well, the latter is practically certain to be of secondary quality.

One well of this type was subjected to high-pressure condensation tests at various rates of flow, and it was observed that at rates of flow of even considerably lower than tubing capacity condensation took place within the reservoir, evidently near the well bore, which was evidenced by the fact that at very low rates of flow the end point of the products recovered in the separator was 465° and at rates of flow considerably lower than tubing capacity the end point of the separator products had dropped to 430°, all tests being carried out at constant temperatures and pressures. In all other wells in this same sand in which the casing was large and set on top of the sand or producing formation, the end point of the products recovered under the same separator pressure and temperature conditions showed no change at any rates of flow up to the full tubing capacity. The contrast observed in these two tests might possibly be owing to the fact that the perforations in one casing, which were confined to the very base of the well, were opposite a section of the sand known to be shaly and therefore offering a high resistance to the passage of gas into the well bore from the formation in the immediate vicinity of the well. There is also the possibility of an additional hazard in this type of completion resulting from the precipitation of fresh water from its vapor phase in the reservoir. If any of this water should wet sands of low permeability these would then offer still higher resistance to the passage of gas through them. The percentage of fresh-water condensate observed in the separators from distillate pools varies in general from 1 per cent to as high as 3.5 per cent of the condensible hydrocarbons, and the greater portion of this fresh-water condensate is precipitated before the products arrive at the surface.

The preparation of the input well to receive the residue gas from the compressors and transmit it to the formation is not likely to offer difficulties if it is completed with 8⅝ or 9⅝-in. casing which has been set on top of the sand. The location of the input wells preferably should be remote from the output or producing wells. The use of wells in which the gas sand has been cased off on completion, followed by perforating the casing, are wholly unsuitable as input wells and, with possibly rare exceptions, will lead to costly troubles. The same statement applies to any gas wells completed in the conventional manner with small casing.

Since all observations and data compiled to date indicate that precipitation of vapor-phase products within the reservoir is the result of pressure decline alone, it is evident that the only means of neutralizing the objectionable effects of such decline lies in the adoption of a plan whereby the recycling of the residue gas may be carried on coincident with development and producing operations and be continued until such time as the unstable distillate-bearing gases have been wholly or partly displaced by the returned residue gas. In pools in which a considerable precipitation has already taken place in the reservoir prior to the insti-

tution of a pressure-maintenance program, it is entirely probable that the return of the residue gas to the formation will serve as an agent of secondary saturation, whereby the previously precipitated products that are distributed or dispersed uniformly throughout the pore spaces of the entire reservoir may be re-vaporized and thus become recoverable. As yet, there are no quantitative figures as to the extent to which this process is taking place in operations now under way. If the recycling process is instituted too late in the life of the pool, there is little possibility that the return residue gas will be able to effect a re-vaporization of the extremely heavy ends which had precipitated at pressures high above those maintained by recycling during the later life of the pool. Observations and study, both in the field and in the laboratory, of the character of retrograde condensation at high pressures strongly support this opinion.

Necessity of Unitized Operations

Although unitized operations offer many advantages in all types of oil and gas development and production, it will no doubt accomplish its greatest contribution to subsurface conservation when applied to the distillate type of pools. Even the strongest critics of unitized operations will scarcely differ with this opinion if all the factors are considered. For oil production, the small tract of land may be developed independently and operated in an efficient manner within itself, but for recycling operations the small tract is totally unsuitable to independent operation, both from a standpoint of physical impossibilities and nonjustification of development expense. As a result of reservoir-pressure decline, precipitation takes place progressively on the small tracts just as well as on the large tracts, but the small tract cannot afford the installation of the necessary equipment to maintain its pressure independently, and therefore must depend upon the maintenance of pressure through some cooperative means. It is barely possible in the few cases in which the reservoir is extremely rich in condensible contents that tracts as small as 160 acres might operate recycling operations independent of others, but this is very doubtful.

A study of the recoverable contents per acre-foot in the reservoir will indicate at once that well spacing must be very wide if commercial success is to be attained, and that the overdrilling of any gas reservoir will contribute nothing in the way of increased recoveries and may burden the operations to the extent that many failures will result from poorly planned development. Unitization is required in this case to eliminate unnecessary drilling. Although its difficulties are well known and recognized, it is almost imperative that it be accepted in the planning of projects where small tracts exist in pools primarily of distillate character, unpopular as it may be in some quarters.

Effects of Blowouts in Distillate Pools

It is an accepted fact that in any distillate pool constant reservoir-pressure decline if uncontrolled results in widespread subsurface physical waste, which is not limited to any restricted section of the pool. Outwardly, it would appear that the damage inflicted upon the field subjected to the uncontrolled output of wild or blowout wells would be more or less confined to the local area of the blowout, and not be the concern of those in the pool who are remotely situated from the center of disturbance. On a closer study of the reactions of blowouts in the light of what is known with respect to retrograde condensation, it is practically certain that the damage these wild wells are capable of inflicting upon the high-content distillate pools is very much greater than their outward appearance would indicate; often the additional subsurface damage may approach losses equal to those of the waste to the air. The resultant subsurface losses, which are distributed to some degree in every part of the pool, should be made the serious concern of every operator within a pool, regardless of his proximity to the disturbance.

References

1. W. N. Lacey and Associates: A.P.I. Project No. 37. *Ind. and Eng. Chem.* (1934–1936) **26, 27, 28.**
2. D. T. MacRoberts: Relation of Gas-well Spacing to Ultimate Recovery. *Trans.* A.I.M.E. (1938) **127,** 146.

DISCUSSION

(*Eugene A. Stephenson presiding*)

L. S. Reid,* Oklahoma City, Okla. (written discussion).—During the past year, the writer has had the opportunity to study the productive characteristics of condensate-producing wells in a number of pools in the Texas-Louisiana Gulf Coast region, using both the usual high-pressure separator equipment and small-scale experimental apparatus designed to control the pressure and temperature variables that are prevalent in investigations of this kind.

In reply to the question of whether or not the optimum accumulation pressure can be raised by lowering the separator temperature, our data indicate that this pressure, at which maximum liquid accumulation is obtained, does not vary for a given hydrocarbon system when the temperature is varied between 50° and 100° F.; the temperature limits to which our investigations have been confined. Normal vaporization accompanies a pressure decrease and retrograde vaporization accompanies a pressure increase above this point; resulting in decreased accumulation in either case when this pressure variation is carried out under constant temperature conditions. Therefore, it seems evident that for every hydrocarbon system of the type under consideration here, there will be found one particular pressure at which both normal and retrograde condensation reach a maximum and the volumetric quantity of the liquid accumulated at this pressure will vary inversely with the temperature. Thus, it is seen that the accumulation resulting from operating the first-stage high-pressure separator at 1200 lb. per sq. in. and 70° F. might be equal in

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volume to that obtained from operating at an optimum pressure of 1000 lb. per sq. in. and 80° F., but would be less than that obtained at 1000 lb. per sq. in. and 70° F. Correlation of our observations indicates that the pressure of optimum accumulation is a function of the well-stream composition. These pressures have been found to range from 800 to 1200 lb. per sq. in. gauge for well streams having a recoverable liquid content ranging from 8 to 25 bbl. per million cubic feet of gas.

It is the writer's opinion that the term "condensible content," as employed by Mr. Foran, should be clarified in future discussions. Obviously, the volume of liquid accumulated at high pressure and atmospheric temperature, say in the order of 1200 lb. per sq. in. and 75° F., will be much greater than the residual liquid volume after the pressure has been reduced to atmosphere, especially since the combined methane, ethane and propane content of the accumulated liquid will constitute from 10 to 20 per cent of the total liquid volume. Moreover, the manner in which the accumulated liquid is stabilized to atmospheric conditions should be designated. Extensive research has shown that very substantial increases in stable condensate recovery may be obtained by means of multistage pressure reduction and separation, when compared to the recovery resulting from subjecting the accumulated liquid to flash vaporization by means of a single pressure reduction to atmosphere. It is suggested that the recovery obtained from single-stage pressure reduction to atmosphere be established as a basis for evaluating the recovery efficiency of stage separation or other stabilization systems; using the term "condensible content" to designate the liquid accumulation obtained from high-pressure gas-liquid separation in the retrograde region.

D. T. MacRoberts,* Houston, Tex.—We have been giving the problem of well spacing in dry natural gas fields considerable study during the past year and we feel that a satisfactory conclusion has been reached. The addition of the recycling operation to this problem, while influencing it in certain ways, does not obviate the conclusion that the problem remains primarily one in economics; however, a new angle is given to the problem in recycling by the necessity of determining not only the number of wells, but the necessary geometrical spacing to avoid shielding effects and the occlusion of wet gas within the reservoir. We feel, however, that the problem is subject to mathematical analysis and hope to do some work eventually on the number and pattern of the wells that will yield an optimum income to the operator.

F. Patten,† Austin, Texas.—We have conducted tests on the products of wells in a number of condensate or distillate pools in Texas, which have shown that the products of these wells leave the sand in the gas phase. At most, only a trace of a liquid phase could have been present at the time the fluids left the reservoir.

Our investigations have corroborated Mr. Foran's statement that reduction in pressure will result in the condensation of an appreciable part of the heavier hydrocarbons. Although it is not possible to calculate accurately the magnitude of the loss that will result in a particular field, we do know that it will increase as wells are drilled to greater depths, and condensate pools are encountered having higher virgin pressures, unless the pressure is maintained by gas recycling or by the introduction of water on the flanks of such fields.

R. L. Huntington,‡ Norman, Okla.—Mr. Foran has presented a complete picture of what may be expected to happen within the distillate reservoir itself as it is produced from year to year. There are several problems with which the industry will be faced when it comes to the production of distillate at the surface of the ground.

* United Gas Pipe Line Co.

† Railroad Commission of Texas.

‡ Director, School of Chemical Engineering, University of Oklahoma.

Recent experimental work at the Univeristy of Oklahoma indicates that a stage-pressure ratio of 4.5 to 1 is the optimum ratio for the production of the maximum amount of liquid at atmospheric pressure. By "stage-pressure ratio" is meant the relationship of the pressure of any one separator to the pressure of the next lower separator in the series. For example, a three-stage setup with atmospheric on the low-stage separator would call for 14.7 by 4.5, or 66 lb. absolute, for the intermediate separator and 66 by 4.5, or 297 lb., on the high-stage separator. In the selection of the number of separators for any battery, however, an economic balance should be made between the cost of the additional separators over and against the increased recovery resulting from such additions.

Freeze-ups resulting from the formation of gas hydrates are causing no small amount of concern to operators that are producing distillate wells at temperatures of 60° F. and lower. These hydrates have been found to consist of combinations of water and hydrocarbons that have melting points considerably higher than that of pure ice. This problem calls for more research on the physical properties of these hydrates as well as preventive measures to be taken in eliminating their formation.

Core Analysis

By Howard C. Pyle* and John E. Sherborne,† Junior Member A.I.M.E.

(San Antonio Meeting and Los Angeles Meeting, October, 1938)

Core analysis is a recent development in the field of petroleum technology. The earliest work on this subject was done in connection with evaluating and planning secondary oil recovery by water-flooding. Present-day analysis of sands of flush fields requires new and independent interpretations of the data provided by cored material. Particular attention is being paid to the development of rapid, routine methods for measuring physical characteristics of sandstone, such as permeability, porosity and grain size, as well as the sand's fluid content.

Permeability may be defined as the fluid-passing capacity of a rock. For a sandstone to be permeable it must be possible to pass a measurable quantity of fluid through the material in a finite period of time. The common unit of permeability is the darcy, which may be defined as the rate of viscous flow, in milliliters per second, of a fluid of one centipoise viscosity through a porous medium having a cross section of one square centimeter, under a pressure gradient of one atmosphere (76.0 cm. Hg) per centimeter.[1] For convenience the subunit millidarcy, or one-thousandth darcy, is often used. Porosity is defined as the fluid-containing capacity of a rock and is usually expressed as a percentage ratio of the total pore volume to the rock or bulk volume. Since measurement of only the effective or communicating pore volume is often made, porosities are distinguished as total or effective.[2,3] Net effective porosity is defined as the net pore volume available for oil and gas. Oil and water content of sand is measured and expressed either as the percentage saturation of the total pores or of the bulk rock. The oil content may also be expressed as the percentage saturation of the net effective pores.

In connection with water-flooding, methods of core analysis were developed to furnish data that could be used in determining the quantity of recoverable oil,[4–6] and the probable rates at which various sands or divisions of a sand open to the wells would take water or produce oil. In flush fields, the analytical data are used to predict the productivity of a cored interval. They indicate the presence of oil, gas and water and may

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* Union Oil Company of California, Los Angeles, California.

† Union Oil Company of California, Compton, California.

[1] References are at the end of the paper.

differentiate the relative productivity of these fluids.[7–9] By application of such information water and excessive gas may be excluded from the production of a well. When cores are analyzed to determine the relative productivity of a cored interval, the tests should be completed as rapidly as possible so that operations at the well are not delayed. When an electric log of a cored interval is to be made, it is desirable to have the core analyses completed and graphically recorded by the time the electric log is available, so that one record may supplement the other.

Porosity, connate water and nonrecoverable oil and gas are determined by core analysis. These factors are necessary in connection with volumetric estimations of oil and gas reserves,[10] and are obtained by core analysis.[10] In addition, special uses of the data are being devised.

Core Sampling and Collection of Well Data

The sampling of cores is a very important part of core analysis. Where the fluid content of the core is to be determined, it is important that the samples be taken as soon as possible in order that evaporation and core contamination by water from the drilling fluid be reduced to a minimum. If sampling is impracticable at the time the core is removed from the well, the best practice is to leave the core in the core barrel until it can be sampled. The mud sheath encompassing the core is not removed until the sampling is started; it is then scraped from the core, but never washed off.

Representative samples of cores may be collected either by systematic sampling at regular intervals or by sampling every visible change in sand character, intermediate samples being taken in the thick, homogeneous sands. The procedure used in sampling should dictate the method of averaging the results obtained. Where the samples have been taken at regular intervals, the test results can be arithmetically averaged. However, where the sampling procedure was dependent upon variations in sand texture, analytical results must be averaged by weighting. As the samples are taken from the core trays they are protected against evaporation by wrapping in lead foil and sealing in tins.

In addition to the core samples, it is desirable to have representative samples of the mud used while coring, and of the oil and water produced from the interval cored. These oil and water samples are often obtainable from adjacent wells or from the well itself if subsequently produced. It is usual practice to record the casing, liner and completion records, as well as the initial production, bottom-hole pressure and temperature, and productivity index of the well. Other pertinent information includes zone or field average initial production, bottom-hole pressure and specific productivity index.

Handling Sample in Laboratory in Preparation for Individual Tests

In the laboratory the samples are divided for the various tests as they are removed from the sealed containers. Ordinarily a division into three parts is made; one for fluid content, one for permeability and porosity, and one for determination of salinity. Any excess of core

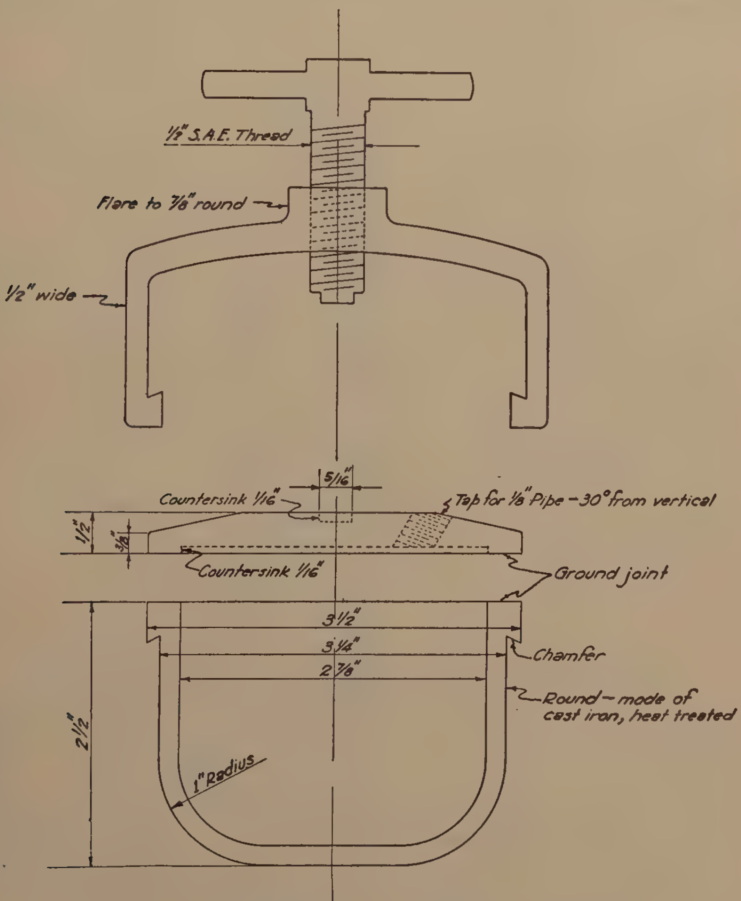

Fig. 1.—Retort of saturation apparatus.

sample is returned to the sealed container to be preserved for future check or special tests. The sample set aside for salinity determination may also be used for grain sizing[11a] and petrographic classification.[11b]

The sample for determination of fluid content is handled first, and as rapidly as possible. It is broken down to pieces 0.5 cm. or less in cross section, and placed in a retort (Fig. 1). Satisfactory results are

usually obtained with retort charges of 150 grams. For the salinity determination a core sample of about 100 grams is reduced to grain size in a mortar or on an assay bucking board, placed in a 200-ml. flask, and dried in an oven for at least 2 hr. at 200° F.

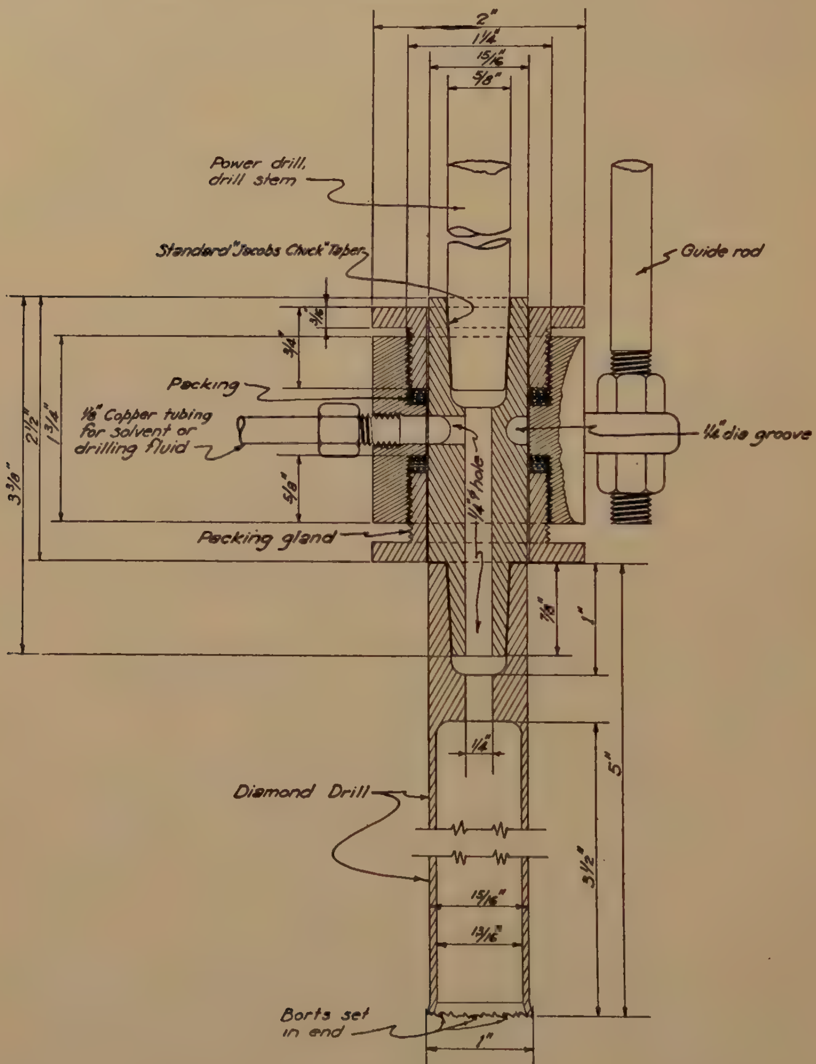

Fig. 2.—Diamond drill.

The sample to be used for permeability and porosity determinations is dimensionally sized in a manner determined by its character. If the sand is sufficiently consolidated to permit, a small core made with a ¾-in. dia. diamond drill (Fig. 2) is taken from it. However, if the sand is too friable for the diamond drill, a rectangular parallelepiped is cut from

it by use of either a knife or a hack-saw blade. Further trimming of this sample may be accomplished by the use of a wire brush rotating at high speed. The finished sample should have a volume approximately equal to a diamond-drilled sample 1 in. long, whenever possible. Except in special cases, samples for permeability determinations should be taken from the

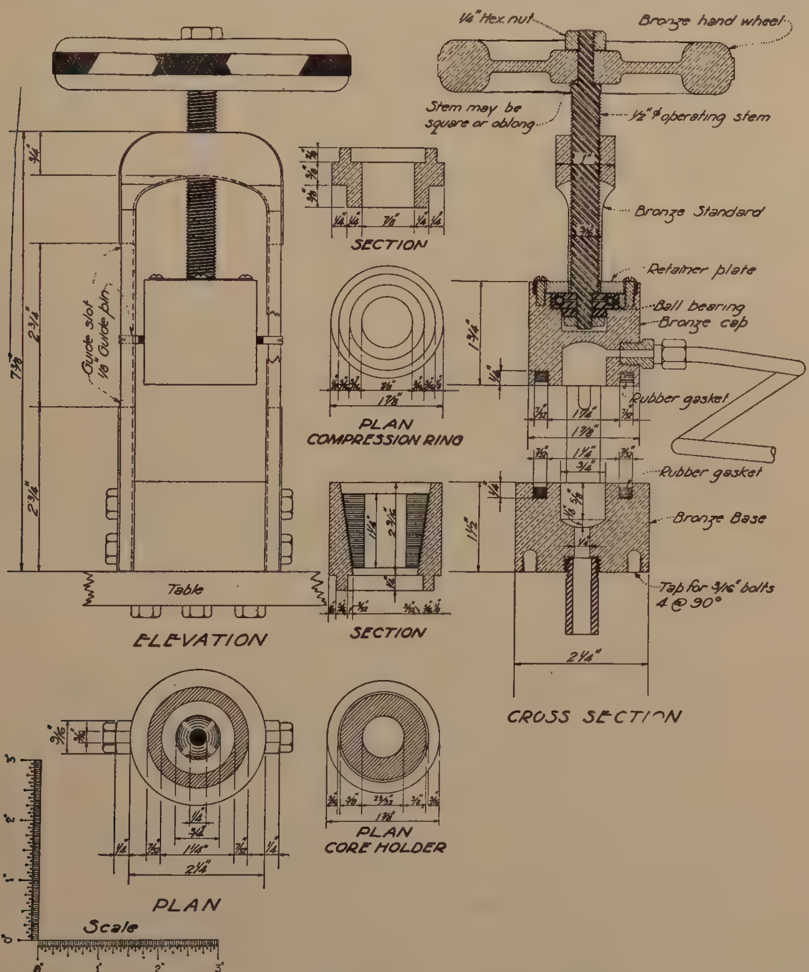

Fig. 3.—Permeability core holder.

cores in such a manner that the air flow of the test can be made parallel to the depositional bedding plane of the sand.

Preparatory to the permeability and porosity determinations, the diamond-drilled sample is placed in a snug-fitting, tapered, Thyokol "stopper" and clamped in a core-holder cell (Fig. 3) for leaching and drying. The leaching and drying apparatus consists of a manifold system in which the temperature can be controlled, which first permits the cir-

culation of hot carbon tetrachloride and then hot dry air (Fig. 4). Experience has shown that samples can be satisfactorily leached and dried in 30 min. by this process when the apparatus is maintained at 150° F. and

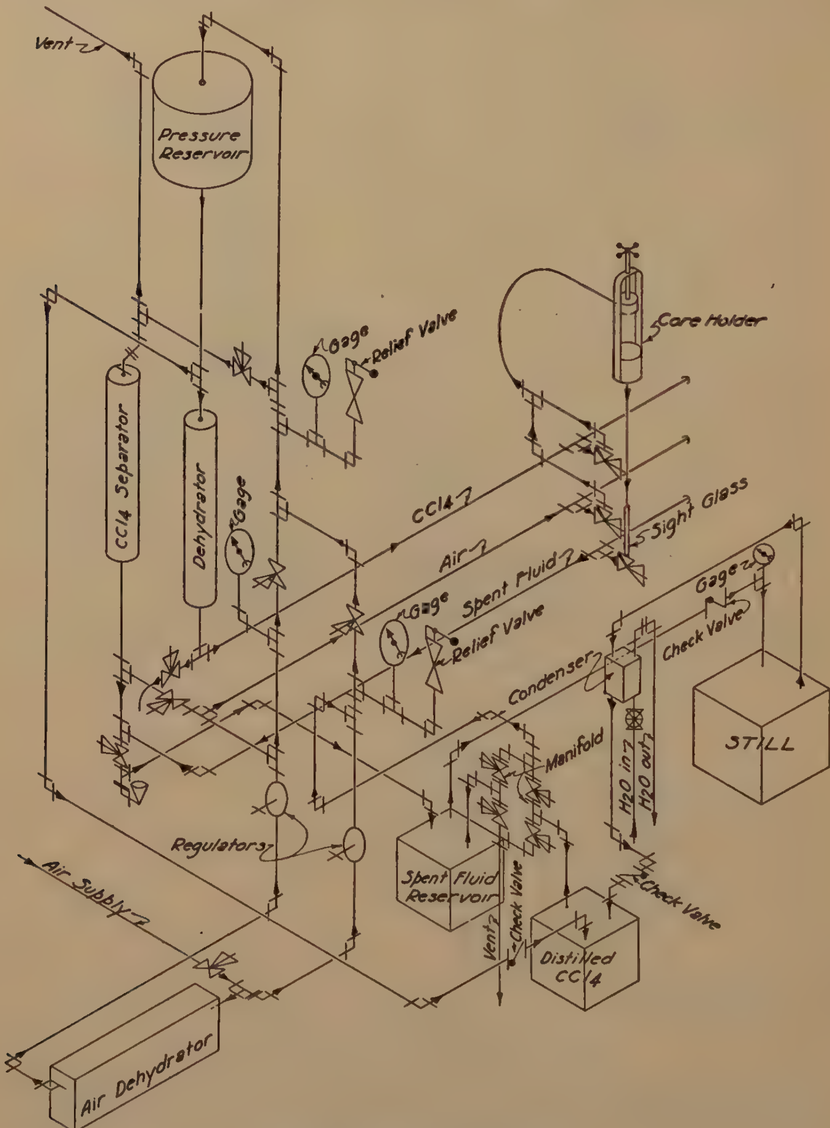

Fig. 4.—Leaching apparatus.

with a differential pressure of 50 lb. per sq. in. across the sand. The hand-trimmed permeability sample is mounted with sealing wax within a brass tube, which replaces the Thyokol "stopper," core holder, and compression ring of the permeability cell. It is leached and dried in a manner similar

to that used for the cylindrical samples, except that the apparatus is maintained at room temperature. After permeability has been measured, the wax mounting is removed and the sample is tested for porosity. All

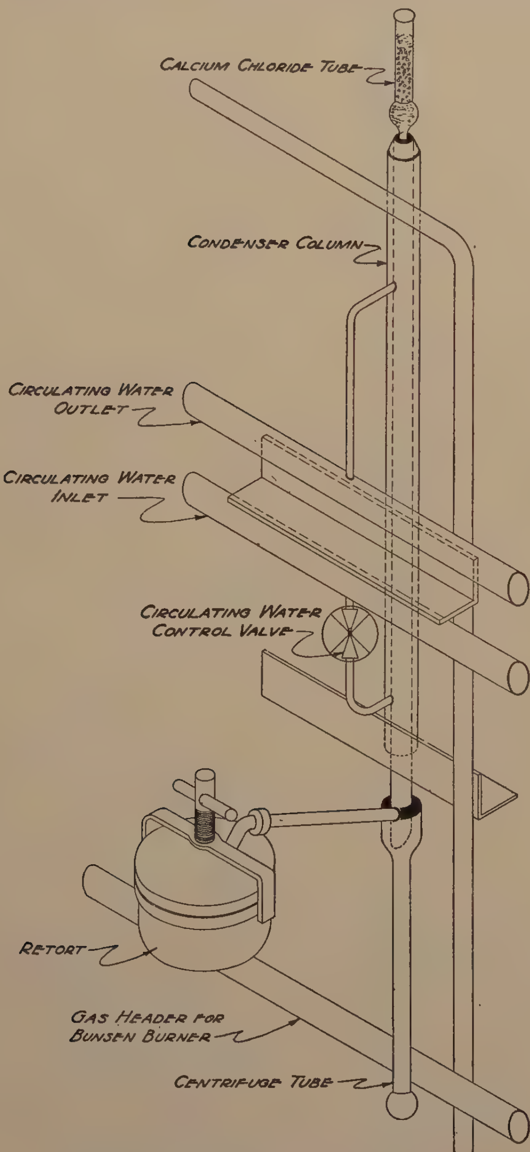

FIG. 5.—SATURATION APPARATUS.

samples are kept in a desiccator after leaching and drying until used for determinations. The carbon tetrachloride used for leaching these test samples is collected and reclaimed by distillation. Fig. 4 includes a flow diagram of this distillation apparatus.

Individual Tests

Saturation

Heat is applied to the charged retorts with a Bunsen flame (Fig. 5) so that the sample in the retort is kept at a temperature of from 350° to 400° F. for 40 min., during which time all of the water and all but the heaviest fractions of the oil are distilled out of the sand. Following this the retort temperature is raised to about 1100° F. and maintained there for at least 20 min. The condensate from this distillation is collected in a special centrifuge tube (Fig. 6). A calcium chloride tube is kept at the top of the condenser to prevent the influx of water with the air that is drawn into the system when the retort cools. After a few minutes has been allowed for drainage and cooling, the material still held in the condenser is swabbed down into the centrifuge tube. If the oil-water interface is within the graduated portion of the tube, the distillates are centrifuged until all of the drops on the sides of the tube are collected with the liquid at the bottom and a sharp boundary exists between the oil and water. If the oil-water interface is below the graduated portion of the tube, water is added from a burette to bring the liquid level to a readable position before centrifuging. When cool, the sand in the retort is transferred to a light-weight crystallizing dish and weighed.

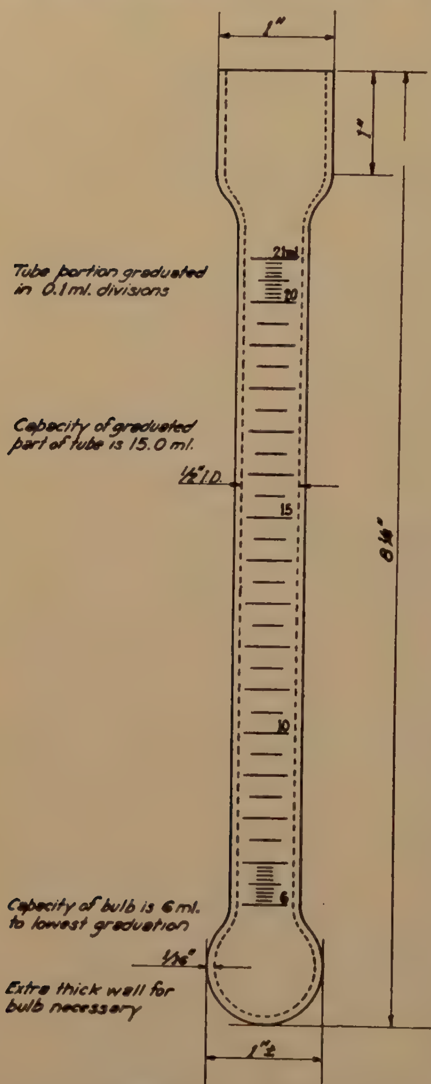

Fig. 6.—Centrifuge tube of saturation apparatus.

Certain volumetric and gravimetric corrections are applied to the distillation data. The sand loses water of crystallization and carbon dioxide, and some of the oil in the sand is lost because of cracking and coking. Reduction of sand weight by loss of water of crystallization and

carbon dioxide is seldom as high as one per cent. Carbon deposited from coking is seldom more than 10 per cent by volume of the oil, and since the total mass of the oil is usually less than 5 per cent of the sand mass, the resultant increase in sand weight is usually less than 0.5 per cent. These gravimetric corrections are partly compensating and of small magnitude, therefore they are usually disregarded.

Retort and condenser are calibrated by mixing measured volumes of oil and water in varying proportions with a given weight of spent sand and measuring the recovery. A large number of such tests using oils of varying types and covering a wide range of gravity show complete recovery of

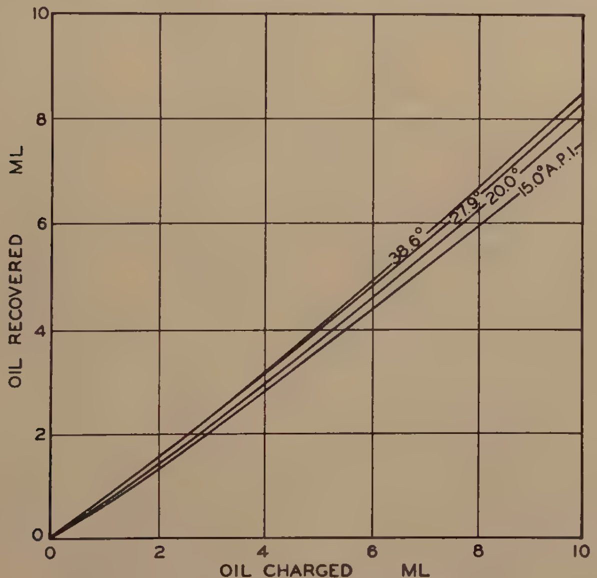

FIG. 7.—SATURATION RETORT CALIBRATION.

water and a recovery of oil varying with its gravity (Fig. 7). With a decrease in gravity, less oil is recovered during the distillation. This is explained by the presence of heavier hydrocarbons and the consequent greater coking. With the lighter oils, the recovery is more uniform over a wide range of gravity; however, the extremely light oils give somewhat lower recoveries because of escape of the more volatile constituents.

While the amount of water of crystallization is negligible as compared with the weight of sand, it is of decided importance in its relation to the volume of water recovered from the pore space. When sands have low porosities and are composed of minerals containing relatively large quantities of associated water, the errors introduced by ignoring water of crystallization may amount to as much as 25 per cent of the interstitial water. Fortunately, this occurs only in extreme cases and, in general, the water of crystallization forms only about 5 or 6 per cent of the

total water recovered. It has been found that the composition of sands from a particular zone or horizon is sufficiently uniform to make unnecessary the determination of the water of crystallization for more than 10 per

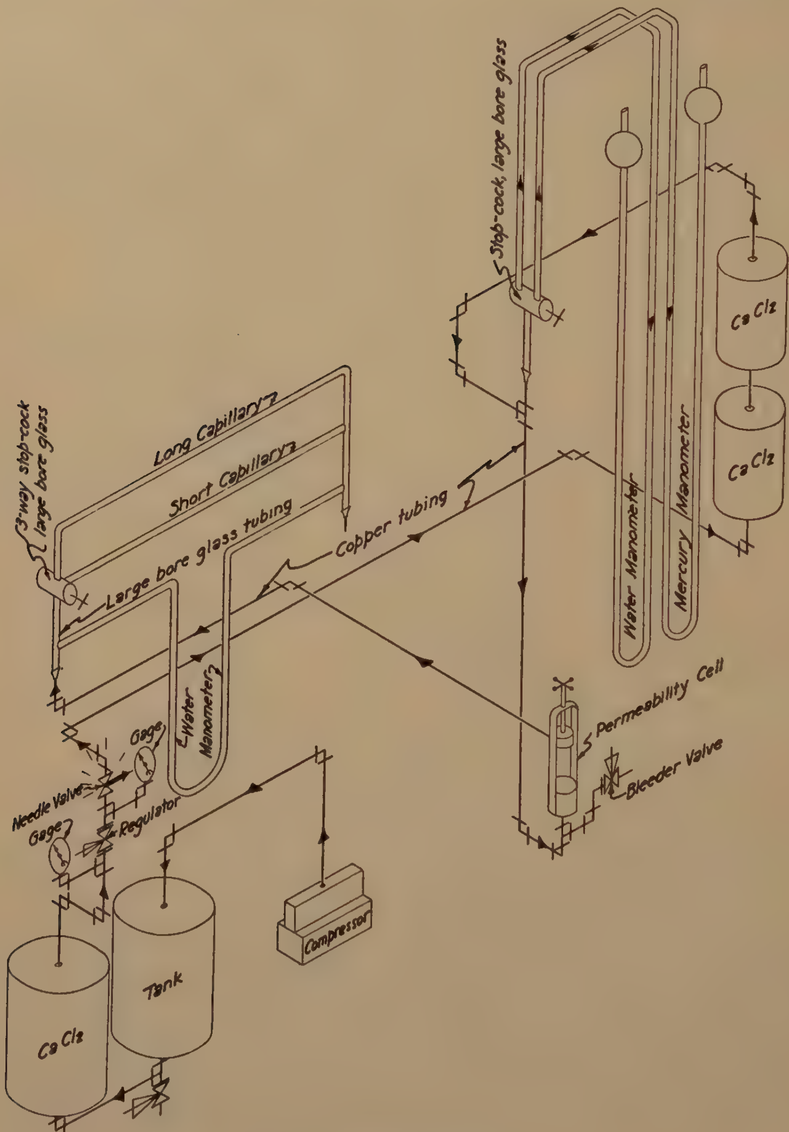

FIG. 8.—PERMEAMETER.

cent of the samples tested. The use of these data will, in all probability, result in a deviation of less than one per cent from the actual amount of interstitial water.

Permeability

Apparatus for measuring permeability is illustrated in Fig. 8. The core holder was designed to take samples of ¾-in. diameter and 1 in. long, or rectangular parallelepiped samples having about the same volume as the cylindrical ones. The design of the air-flow meter allows for measurement of permeability of from 1 millidarcy to 10 darcys, with a higher range of 50 darcys not now used. This apparatus is calibrated by placing a plug in the core holder in such a manner that varying quantities of air are passed through at given upstream pressures. This flowing air passes through the flowmeter and is then caught in an inverted graduate

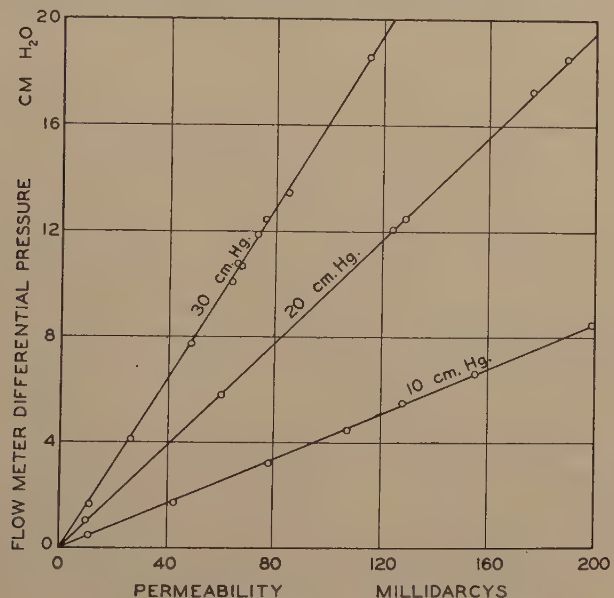

FIG. 9.—PERMEAMETER CALIBRATION CURVES.

at atmospheric pressure by water displacement. The amount of air caught in a given interval of time is related to the differential pressure across the capillary of the flowmeter. Taking into consideration the temperature of the air and the barometric pressure while calibrating, curves are drawn (Fig. 9) for cylindrical samples of the standard size for air at a temperature of 68° F. (20° C.). Additional curves have been constructed to correct permeability when dimensions of cylindrical samples deviate from the standard size. A change in air temperature of 10° F. results in approximately 1 per cent error in permeability, consequently suitable temperature corrections are made.

For permeability measurements, cylindrical samples of measured length and diameter are placed in tapered Thyokol "stoppers" and clamped in the cell. Since sample cylinders taken from various sands

have slightly different diameters, it is necessary to fit them into tapered "stoppers" of proper internal diameter. Air is allowed to flow through the sample at one of the standard pressures and the differential manometer of the flowmeter is read; care being taken to clamp the sample in the cell tight enough to prevent leakage between the sample and the "stopper." The permeameter is so designed that, with back pressures available, turbulent flow cannot exist within the apparatus. Permeability measurements of rectangular parallelepiped samples are made as are those of cylindrical samples, except that they are held in sealing wax within a brass tube, which replaces the Thyokol "stopper," core holder and compression ring of the cell. Individual calculations are necessary for each of these tests.

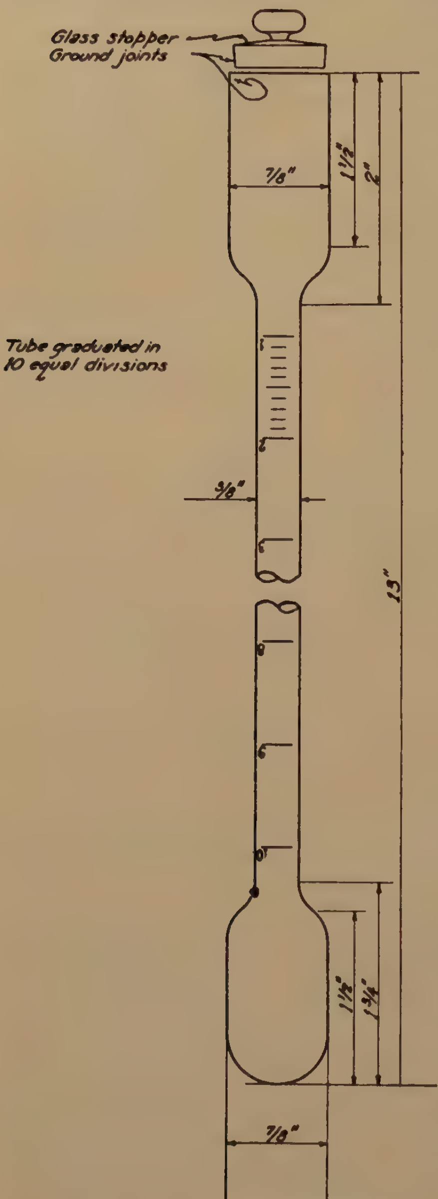

Fig. 10.—Bulk volumeter.

Porosity

Tested permeability samples are used for porosity determinations. All samples are weighed to the closest 1/100 of a gram, to make possible correlation of data from the various tests. The bulk volume of the porosity sample is measured by displacement of mercury in a glass volumeter (Fig. 10). For this the mercury level in the tube of the volumeter is observed, the sample introduced by tipping the vessel upside down, and the mercury level again read after the volumeter has been returned to its first position. The difference in the two observations, read to the closest 1/10 ml., is the bulk volume of the sample. A ground taper joint permits replacement of the volumeter stopper to identical position, assuring constant volume for the apparatus.

Following determination of bulk volume, the sample is carefully ground to grain size in a porcelain mortar and then removed to a tube similar to the one illustrated in Fig. 6, constructed, however, with a 15-ml. rather than a 6-ml. bulb. Before the addition of the sand material, the tube is filled with a measured volume of tetrachlorethane and this quantity subtracted from the new volume obtained after the addition of the sand gives the sand-grain volume. The total porosity of the sample is calculated by dividing the difference between its bulk volume and its sand-grain volume by its bulk volume. This method is sufficiently accurate for core analysis and has the distinct advantage of being rapid. The following tabulation compares percentages of porosity determined on duplicate samples by this method and by a Coberly porosimeter:

Described Method	Coberly Porosimeter
17.1	16.92
20.1	20.68
19.3	18.05
10.2	10.39
25.9	26.00

Salinity

The measurement of interstitial water salinity consists in determining the amount of chloride ion that can be leached from the sample, it being assumed that there are no undissolved chlorides in the sand itself. After having been reduced to grain size and dried, the sample is weighed. It is then shaken vigorously with 120 ml. of water for 3 or 4 min. and allowed to stand in a stoppered flask for at least one hour, after which period the water and sand are separated by filtration. Of the filtrate, a 50-ml. portion is transferred to a small flask, neutralized if necessary, and titrated with silver nitrate, using potassium chromate as an indicator. If the quantity of oil in the sample exceeds 4 ml. per 100 grams of sand, the sample should be washed several times with a chloride-free oil solvent before drying.

During the development of this method, samples of sand varying from argillaceous and poorly sorted to uniformly coarse grained were leached until they were free of chlorides as indicated by titration with silver nitrate. To these leached sands, brines of known chloride content were added in varying quantities. Test samples were then dried, leached and titrated. It was found that no measurable amount of chloride in the water was occluded on the sand material and that the procedure obtained all of the free chloride ion. The use of warm water for leaching was found to be of negligible value. Drying the sand at a temperature much above 200° F. resulted in a loss of chloride, therefore this drying is done in an oven in which the temperature of the air is controlled.

Size Analysis

The grains of sandstone material are classified for size with U. S. (Tyler) standard screens. A sample to be screened is reduced to grain size, leached of oil, dried and weighed. It is then shaken through a set of screens on a rotating and tapping machine. The sand material retained on each screen is removed and weighed and weight percentages are calculated. For comparative purposes it is common practice to plot cumulative percentages by weight against screen-opening size, using a logarithmic scale for the sizes of the openings.

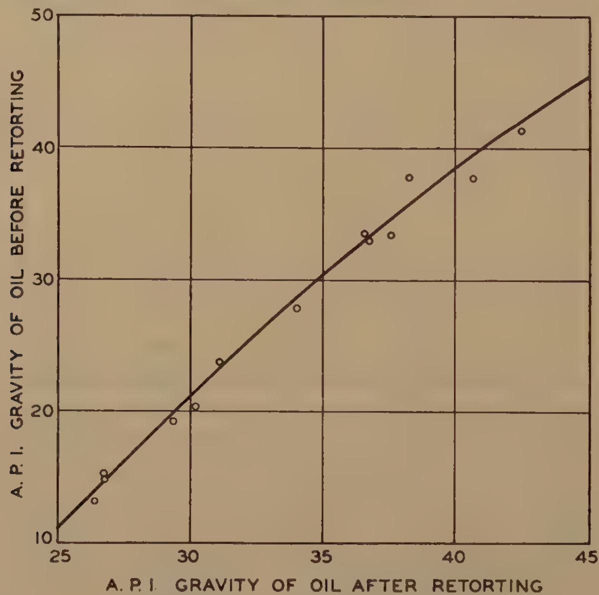

FIG. 11.—EFFECT OF RETORTING ON OIL GRAVITY.

Oil Gravity

Measurement of the gravity of oil found in the sand samples analyzed is of interest when these samples are from a stratigraphic horizon or district from which previous production has not been obtained. Furthermore, it is necessary to know the gravity of the oil distilled in order that the proper factor may be used in calculating percentage of oil saturations. Fig. 11 shows the effect of distillation on the gravity of oil. It is based upon a series of gravimetric determinations of composite samples of oil from sands of a given producing zone. Upon completion of the well the gravity of the oil produced was compared with that previously determined by testing samples of oil sand. These data have been supplemented by results obtained with oils used in the calibration of the retorts. It is important that the oils be thoroughly dried before the gravity

determination is made. This is accomplished by allowing the oil to be in intimate contact with calcium chloride for a period of time. Since

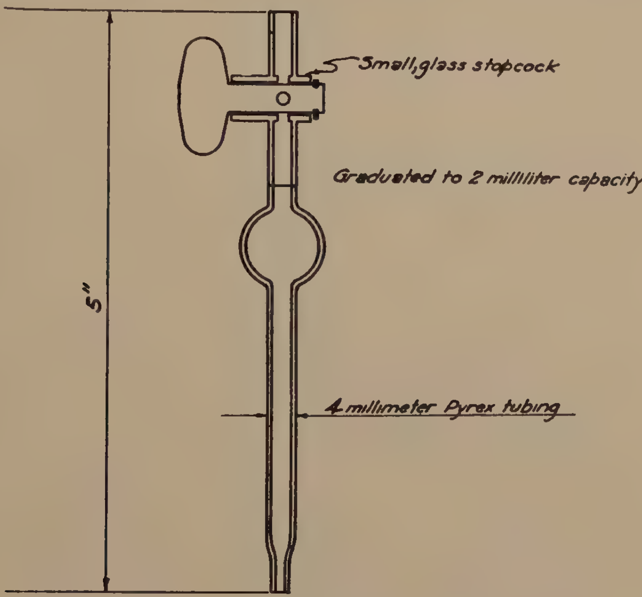

FIG. 12.—SPECIAL PICNOMETER FOR CORE ANALYSIS.

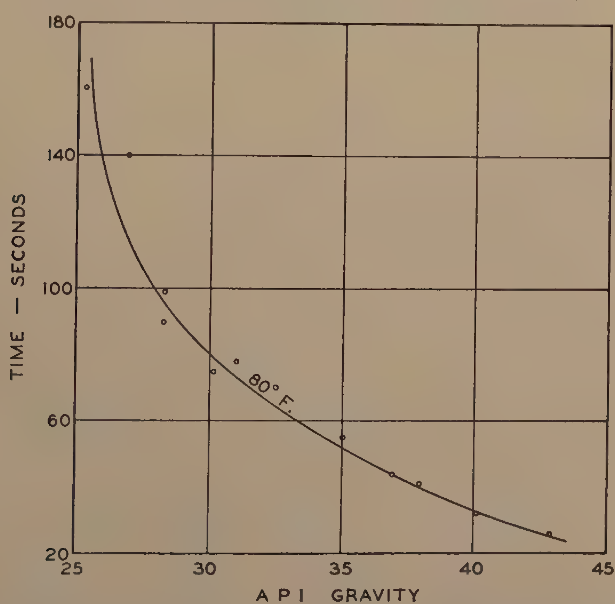

FIG. 13.—CALIBRATION FOR CAPILLARY METHOD OF DETERMINING OIL GRAVITY.

there is often only a very small quantity of oil with which to make the gravimetric measurements, a specially designed picnometer of only 2 ml. capacity is used when necessary (Fig. 12).

Another method has been developed for testing small quantities of oil—based on a correlation between the capillarity and the gravity of an oil. One end of a strip of ordinary filter paper, 6 mm. wide, is immersed 5 mm. into the oil, and the time required for the oil to rise $1\frac{1}{2}$ cm. on the paper is noted. Fig. 13 relates the time of capillary rise of oils of varying gravity at a constant temperature of 80° F. It is assumed that these curves are applicable only to oils of somewhat similar composition, and it should be remembered that the oils used in calibration were distilled and must, therefore, be corrected (Fig. 11) in order to obtain the gravities of crude samples.

Correlation of Measurements

The procedure of the various measurements has been planned so that a ready correlation of the various quantities obtained can be made on a mass basis. Fluid volumes obtained in the saturation process are related to the mass of the sand and expressed as milliliters of fluid per 100 grams of dry, unprocessed sand. Similarly, in addition to expressing porosity as the percentage of the total volume of the sample occupied by the volume of the total pore space. it is expressed as milliliters of total pore space per 100 grams of dry sand. Oil and water saturation can, therefore, be calculated by the following formulas:

$$N = \frac{V_0}{V_p} \times 100 \qquad [1]$$

and

$$N' = \frac{V_w}{V_p} \times 100 \qquad [2]$$

where N = per cent of pore space filled with oil,
N' = per cent of pore space filled with water,
V_0 = volume of oil per unit mass of sand, ml. per 100 grams dry sand,
V_w = volume of water per unit mass of sand, ml. per 100 grams dry sand,
V_p = volume of total pore space of sand, ml. per 100 grams dry sand.

Chloride-ion concentration in the water obtained from the core sample can be computed in a similar manner, as follows:

$$C = \frac{kM_s}{V_w} \qquad [3]$$

where C = concentration of chloride ion expressed as grains of sodium chloride per gallon of water,
M_s = amount of chloride ion expressed as milligrams of sodium chloride per 100 grams of dry sand,

V_w = volume of water per unit mass of sand, ml. per 100 grams dry sand,

k = factor for converting from milligrams per milliliter to grains per gallons.

Consideration and Use of Results

Interrelation of Data Obtained

Many of the measurable physical characteristics of sandstone and its fluid content are interrelated and some correlations are necessary in

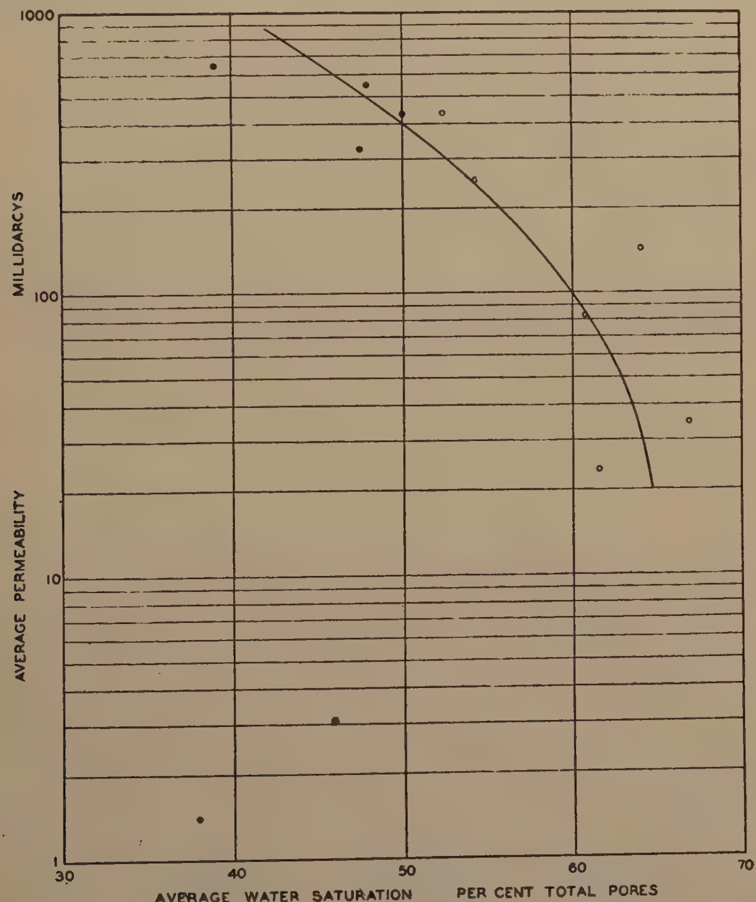

Fig. 14.—Correlation of permeability with water saturation of sands.

understanding and interpreting the analytical data obtained. An inverse relation between connate water and permeability has been noted,[12] the water saturation increasing as the permeability decreases. Quantitative methods of determining the connate-water content of sands have been

developed,[12,13] but in the routine coring of oil formations it is impracticable either to exclude the possibility of contaminating cores with water or to determine the extent of such contamination. It is therefore desirable to know what amount of water saturation is to be encountered in cores secured under normal drilling conditions with the use of mud. Such amounts have been related to permeability in Fig. 14. Because of the wide spread of individually plotted values, average permeability and water saturation were used. Only averages representative of complete producing intervals in wells that produced oil and gas exclusively were used.

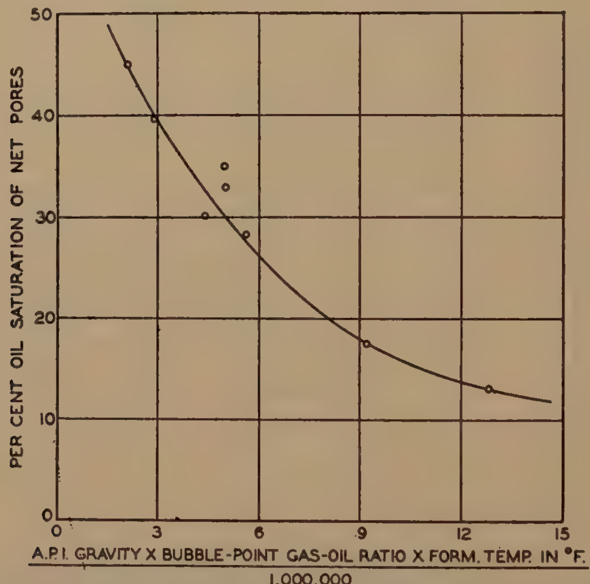

FIG. 15.—APPARENT "GAS DRIVE" NONRECOVERABLE OIL FACTORS.

Oil saturation of sand samples from oil-producing formations varies greatly. For correlation purposes the oil content of the sand samples has been calculated as percentage of saturation of the net pore space available for oil and gas. This made it necessary to assume quantities of connate water, as no definite data were available. The assumed data were similar to those reported by Schilthuis[12] for Anahuac and Tomball fields, although slightly lower in value. Considering that oil is expelled from a core sand sample as it is removed from a well to the atmosphere just as the gas-drive oil production is from the formation itself, the residual oil should be correlative with oil expulsive and resistive forces. Fig. 15 correlates residual oil saturation of net pores with the oil A.P.I. gravity, bubble-point gas-oil ratio, and formation temperature. Here, the A.P.I. gravity of an oil is assumed to vary inversely with its surface tension and viscosity.

Salinity of interstitial water has been found to vary inversely with the resistivity values of electric logs (Figs. 16 and 17). In Fig. 17 figures for two wells in the same field but in different zones are shown. The salinity cannot be expected to give the same correlation with resistivity from

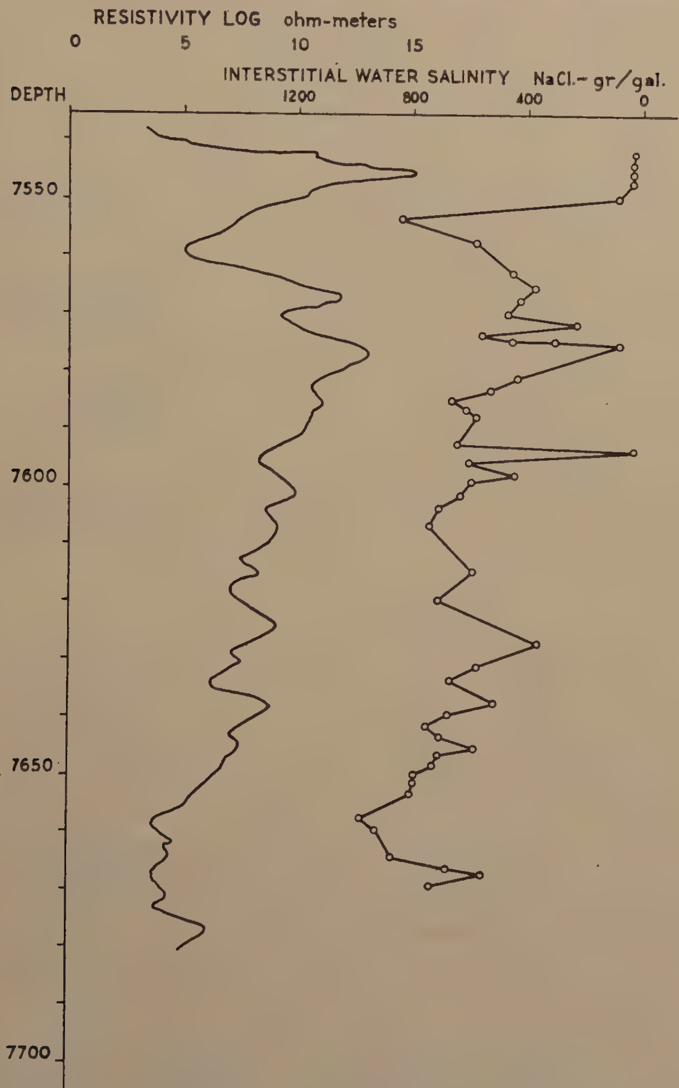

FIG. 16.—RESISTIVITY VS. INTERSTITIAL WATER SALINITY

different wells because the resistivity curves are greatly affected by the pressures involved, the nature of the drilling fluid, the mechanical details of the resistivity-measuring device, and a number of other factors. However, it is felt that, having the data, one can weight the resistivity

curve to make it more useful in evaluating a particular formation as to its oil or water content. This is illustrated in Fig. 22 and is discussed later. Of the salinity and resistivity values selected for use in Fig. 17, only those that remained practically constant for more than 5 ft. of formation were used. Any marked decrease in interstitial water salinity from such a plotted relationship may indicate excessive contamination of the connate water in a core sample by water from the drilling fluid.

Graphic Presentation of Data Obtained

Because of the large number and varying nature of the analytical tests that are usually made on core samples from a prospective producing

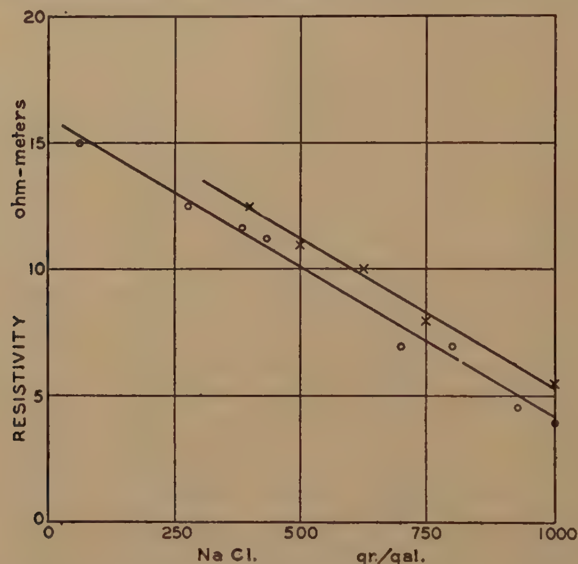

FIG. 17.—RESISTIVITY VS. INTERSTITIAL WATER SALINITY.

formation, it is important that a uniform and comprehensive method of graphic presentation of the test results be used. Figs. 18, 19 and 20 illustrate a fairly satisfactory method of presentation, although the depth scale used has been foreshortened. In addition to the analytical data, cored and electric logs of the interval are included. For convenience, the figures for oil and water saturation are plotted as percentages of the total pore space, the oil from the left and the water from the right. The distance between these two plotted quantities represents the percentage of total pore space unaccounted for by analysis. In the formation this space presumably was occupied either by oil, subsequently produced, or by gas. Shrinkage, of course, reduces the reported volume of oil in the formation.

When considered in relation to other test data, the ratio of oil to water in the cores has proved useful in predicting the nature and relative

amounts of producible fluids. For this reason oil-water ratios are plotted along with the specific test data. Casing and subsequent completion data are plotted adjacent to the graphic log of the formation cored. Notations of formation-test intervals are also included in this column.

Prediction of Productivity

In order to predict the productivity of a cored interval from analytical data it is helpful to reconstruct the total fluid content of the permeable

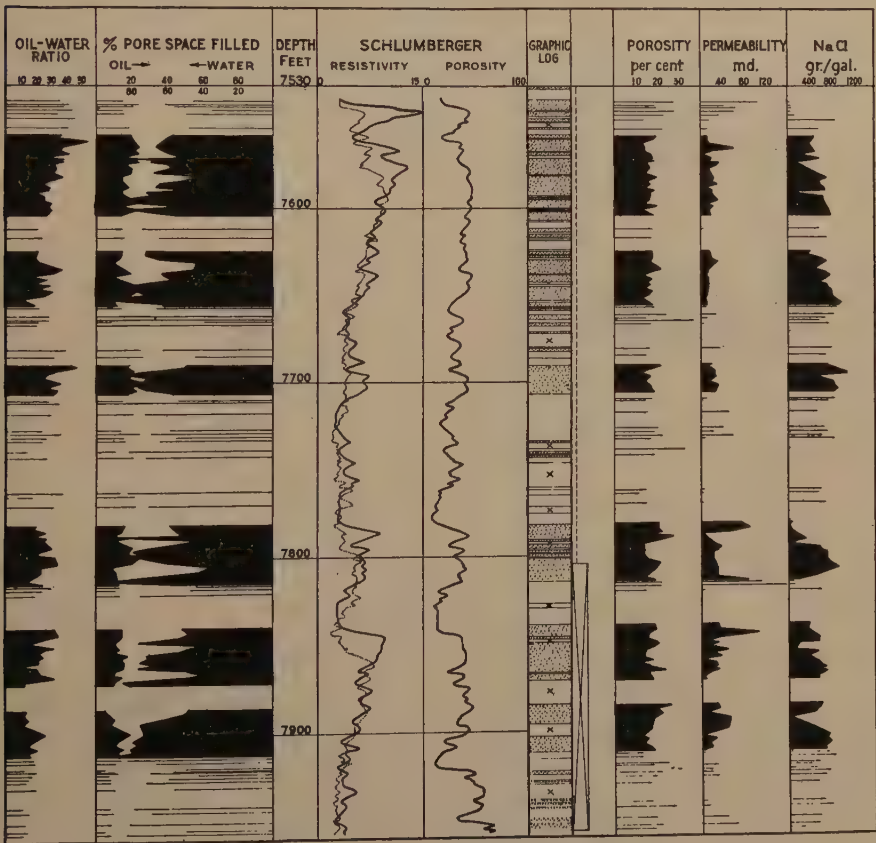

FIG. 18.—CORE ANALYSIS, WELL A.

sands in place. Sands that contain only water, but no more than that which would be normally connate, would produce gas. Sands containing a normal amount of oil, or less, with more than expected water would produce water and could be considered to have been oil-producing sands encroached by edge water. The sands containing apparently normal amounts of both oil and water would produce oil along with solution gas plus a possible amount of additional gas from oil within the area affected by the pressure drop at the well.

Normal oil-water ratios for oil-producing sands can be calculated from data set forth in Figs. 14 and 15. In advance of a production test, if the bubble-point gas-oil ratio and formation temperature are known, it is possible to calculate normal oil-water ratios as a function of sand permeability. This offers a convenient method of checking the analytical data from each sample tested for critical values. For sands that have thus been determined to be productive of oil, it is possible to estimate the prob-

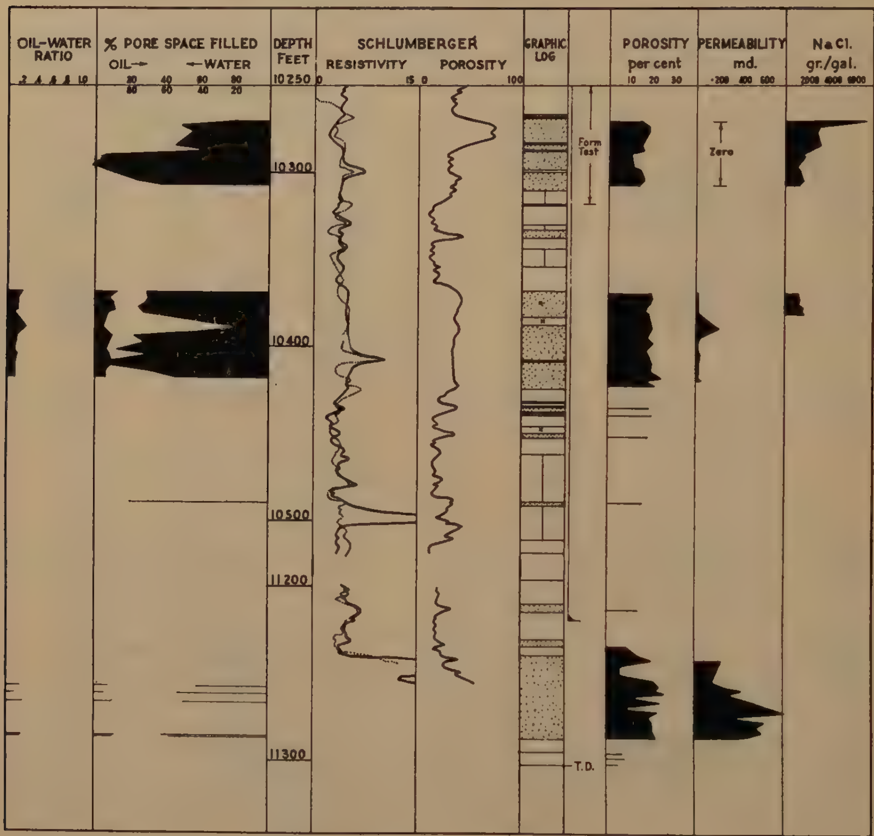

FIG. 19.—CORE ANALYSIS, WELL B.

able rate at which this oil can be produced. Fig. 21 relates average permeabilities as determined by air flow through clean, dry sands, with specific productivity indices.[14] These indices are for water-free oils of from 29° to 39° A.P.I. gravity, produced with only moderate amounts of gas.*

* The oils and gases involved in Fig. 21 are of the same general types as those described by Sage and Lacey in Drilling and Production Practice, Amer. Petr. Inst., 1935, pp. 141–147.

Exceptions to the rule that high resistivity in sands of good permeability indicate commercially productive oil are often detectable on comparing electric logs with core analyses. Fig. 22 illustrates such an exception. The sands encountered from 4340 to 4410 ft. in the well appear from the electric log to be well saturated with oil and permeable. Core analyses show that these sands are permeable, but that relatively high resistivity is due to the low salinity of interstitial water.

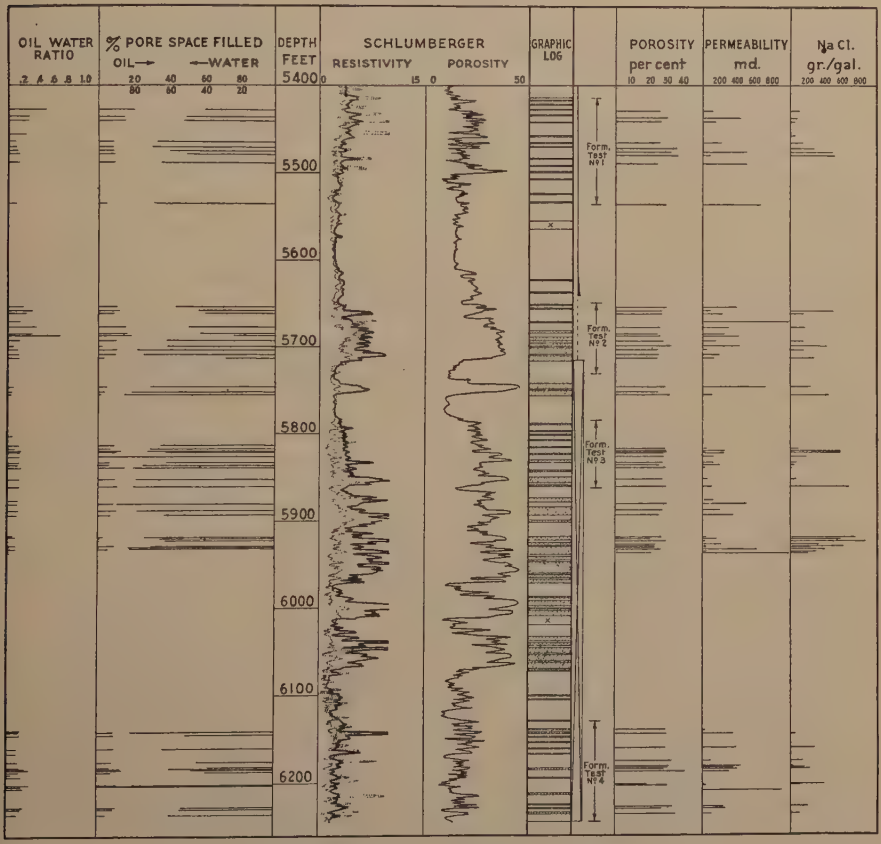

FIG. 20.—CORE ANALYSIS, WELL C.

Analytical data for well A are graphically set forth in Fig. 18. The interval cored and tested represents the lower half of the formation included in the completion of the well. Experience, however, has indicated that this lower half is roughly representative of the whole productive interval and that no productive water or gas sands occur in the upper half. No unusual variations occur in the porosity, permeability or in salinities of interstitial water. Saturation is normal except below 7900 ft., where the percentage of pore space filled with water is high and the oil-water ratio is low. Therefore the hole was plugged to 7816 ft. and the

well completed producing 400 bbl. per day, cutting less than 5 per cent water, and with a gas-oil ratio of 600 cu. ft. per barrel. The water produced contained from 850 to 1070 grains per gallon sodium chloride.

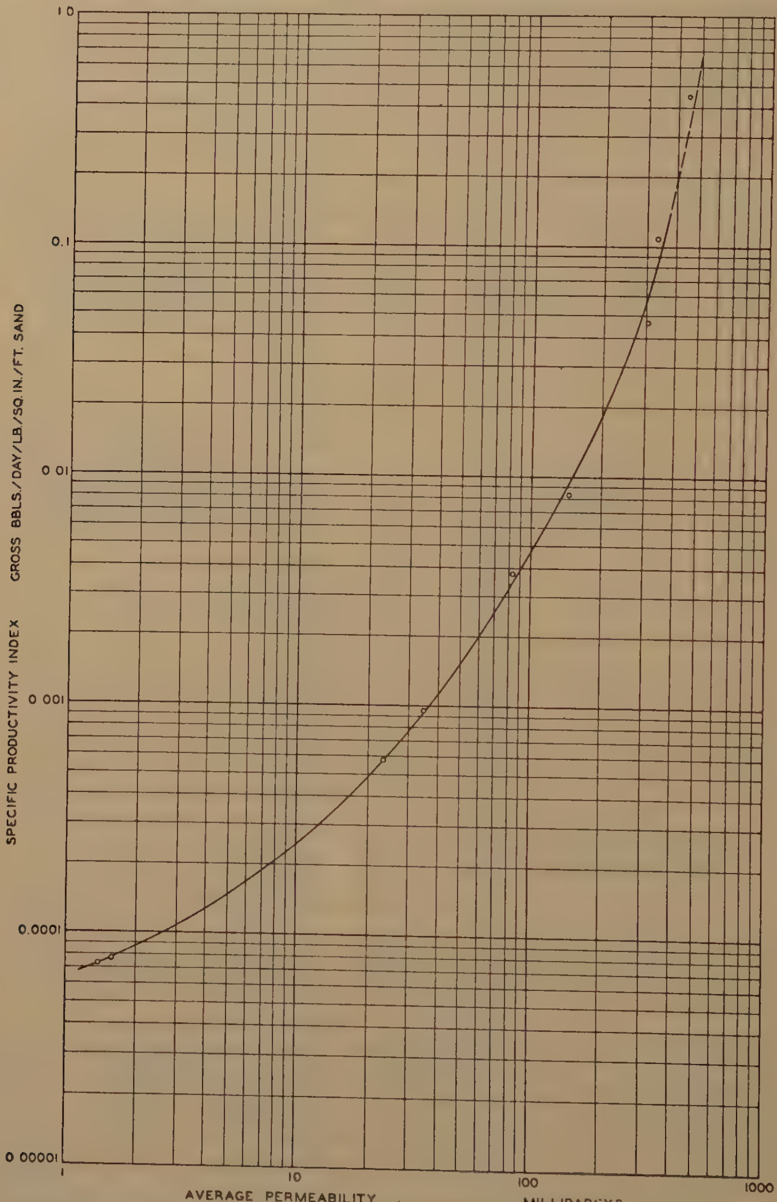

FIG. 21.—CORRELATION OF PERMEABILITY WITH WELL PRODUCTIVITY.

The analytical data of well B (Fig. 19) are interesting in that they show large variations in permeability and interstitial water salinity.

A formation test of the upper interval gave a rise of 880 ft., or 22 cu. ft. of fluid with 7500 ft. of drill pipe dry, in 2½ hr. Most of the 22 cu. ft. of fluid that entered the drill pipe was water, titrating 1766 to 1865 grains per gallon sodium chloride. This would be expected, for while the presence of gas is indicated above 10,285 ft., the permeability of that formation is zero. The interval tested at 10,400 ft. suggests the presence of producible oil, but the permeability of the sand is relatively low and it would not produce commercial quantities of oil. The test results of the

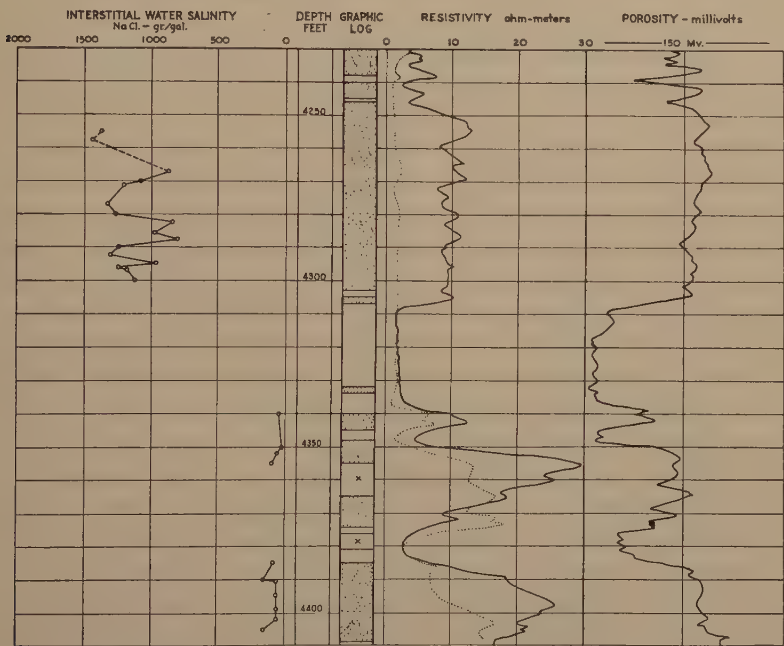

FIG. 22.—CORRELATION OF LOW INTERSTITIAL WATER SALINITY WITH HIGH RESISTIVITY.

interval below 11,240 ft. indicate commercially producible oil with solution gas only. The interstitial water has an exceedingly low salinity. Upon completion in this interval the well produced oil with a water cut of less than one per cent and with a gas-oil ratio of 900 cu. ft. per barrel. The oil-producing potential of the well was in excess of 15,000 bbl. per day.

Well C, Fig. 20, was chosen for illustrative purposes because of the four formation tests that were made of intervals from which cores were analyzed. The first interval tested resulted in gas blowing out 1400 ft. of fluid from the drill pipe after the foot valve had been open 37 min. After this valve was closed, there remained in the drill pipe 1200 ft. of oil, 800 ft. of water, titrating 1341 grains per gallon sodium chloride and 1800 ft. of mud. The foot valve had apparently opened while jarring to loosen the

formation packer, allowing the entry of mud. The relatively high water and low oil content of the sand below 5450 ft. indicated the source of the recovered water. Fluid rose to the surface in 25 min. in the second interval tested and was allowed to blow to the sump for 25 min., producing mostly gas with some oil and water. Following the blow period the well was shut in for 35 min. before the foot valve was closed. When the drill pipe was removed from the hole, 2300 ft. of oil, 1300 ft. of oil and water, and 500 ft. of water titrating 1300 grains per gallon sodium chloride were recovered. Here again, the relatively high water and low oil content of the sand below 5700 ft. indicate the source of the recovered water. The well was later completed in this interval, producing 450 bbl. per day gross oil cutting 46 per cent water, and with a gas-oil ratio of 630 cu. ft. per barrel.

There was a light gas blow with no fluid produced at the surface during the time the foot valve was open on the third formation test. When the drill pipe was removed from the hole, 4200 ft. of mud and water with only a trace of oil was recovered. The water titrated 1204 grains per gallon sodium chloride. Core-analysis data for this interval, when compared with those of tests 1 and 2 clearly indicate this water production. Formation test No. 4 was made in an interval that looked most promising on reviewing the core data. Relatively high water saturations were found in only two samples tested, and these sands had low permeabilities. In this test gas blew at the surface in 6 min., mud and water in 34 min., and oil in 40 min. There were recovered from the drill pipe 350 ft. of oil and 90 ft. of slightly muddy water. A sample of the recovered water tested 308 grains per gallon sodium chloride. It is interesting to note that the average salinity of the interstitial water of the first three test intervals is decidedly less than that of the water recovered during the formation tests. Water subsequently produced from the second interval tested has a salinity of 1284 grains per gallon sodium chloride. The water phase of the mud used in drilling this part of the formation contained approximately 75 grains per gallon sodium chloride. No explanation is offered for the differences in water salinities, it being unlikely that contamination by water from the drilling fluid alone could be the cause unless some flushing took place.

Liner Specifications

Selection of the proper mesh size for screen pipe can be made from the results of size analyses of unconsolidated sands. Experiments performed by Coberly[15] using unconsolidated oil sands with typical grain-size distribution indicate that stable sand bridges will form if the pipe slot perforation width does not exceed twice the screen opening, which retains 10 per cent of the sand samples.

When the presence of producible gas or water sand is distinguished in association with producible oil sand, it can be excluded from the well-completion interval by the use of blanks in the perforated liner behind which cement is placed. Similarly, blank pipe can be cemented opposite a nonproductive formation, between two productive intervals allowing the well to be subsequently selectively produced.

Data Pertinent to Reserve Estimates

Estimates of oil and gas reserves are necessary in the orderly planning of the exploitation of these reserves. Where properties have been rapidly developed and production allowed to continue at an unrestricted rate, production-rate decline curves have proved useful in these estimates, This type of development and production is not common at the present time, however, and it has been found that decline curves of restricted production do not furnish dependable bases for estimates. Therefore attention is being given to volumetric methods of estimating these reserves. Many of the factors used in estimating the capacity of oil formations are obtainable by core analyses. Producible sand classification and porosity are directly obtainable, while connate-water content is usually only available from generalized correlations[12] (Fig. 14).

Where samples have been taken from formations produced to depletion or encroached by edge water, it is possible to obtain directly by core-analysis methods the volumes of nonrecoverable oil. However, the application of these data to formations that have not been depleted or encroached by edge water necessitate that they be correlated with certain known sand and oil characteristics. Since it is probable that cores from undepleted formations follow closely through the gas-drive production life of the formation itself on being removed from the well to the surface, Fig. 15 illustrates one possible correlation. For correlating nonrecoverable oil in sands encroached by edge water, the curve of Fig. 15 would undoubtedly have to be modified somewhat. The limited amount of information available on sands in which the edge water is known to have encroached suggests that only slightly more oil is expelled from the formation by water encroachment than when gas expansion is allowed to continue to atmospheric pressure. There will be an appreciable difference in the volumes of nonrecoverable gas, however, dependent upon whether the sands continue to produce oil with pressures declining to approximately that of the atmosphere or are encroached by edge water at some intermediate pressure.

Conclusions

Equipment and procedure have been developed for making routine measurements of certain physical characteristics of sands and of their

fluid contents. These methods have proved to be rapid and of a satisfactory accuracy. Correlations of some of the data obtained have made possible in many instances the prediction of the relative volume and nature of the fluids producible from wells. It is apparent, however, that more analytical data are necessary to complete these correlations and to help in developing others.

Quantitative information, necessary for volumetric estimates of reserves is obtainable by core analyses. In addition, there are many special applications of the data, some of which have been described.

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DISCUSSION

(Paul Weaver presiding)

H. G. Botset,* Pittsburgh, Pa.—This paper is of interest for at least two principal reasons: (1) it demonstrates definitely the value and application of a complete core

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analysis to production problems; (2) it shows conclusively that it is both possible and practical to use core analysis as a control in drilling wells. The methods described are so rapid that the results are available in time to serve as a guide in the proper completion of the well, and yet accuracy has not been sacrificed to speed. The authors are aware of the many sources of error in core analysis and have taken proper precautions to insure the accuracy of their results. They have also shown how much knowledge can be gained about producing formations by the proper interpretation of all the data that are obtained in a complete core analysis.

Bottom-hole Measurements in Pumping Wells

By J. J. Jakosky,* Member A.I.M.E.

(San Antonio Meeting, October, 1938)

The fundamental hydrodynamic principles governing the production of oil from wells have been carefully studied and evaluated by many investigators. These prior studies are quite complete and cover virtually the entire field of oil production and recovery.[1] One of the most important measurements in production studies is that of the bottom-hole pressure at various rates of production.[2] It is the purpose of this paper to outline the technique and economics of fluid-level measurements as applied to pumping wells and to review briefly other methods for obtaining bottom-hole data.

The applications of bottom-hole pressure or fluid-level measurements are based on simple hydrodynamic principles. Under equilibrium conditions,

$$p_{bh} = hd + p_g + p_{ch} \qquad [1]$$

when p_{bh} = bottom-hole pressure, lb. per sq. in. absolute,
h = height of fluid in well, ft.,
d = average fluid density, lb. per sq. in. per foot,
p_g = weight of section of gas column 1 in. square from fluid level to casinghead,
p_{ch} = casinghead pressure, lb. per sq. in. absolute.

In words, equation 1 states that the bottom-hole pressure is equal to the weight hd of the column of fluid plus the weight of the column of gas between the fluid and the casinghead plus the casinghead pressure.

At moderate rates of flow, the rate of production is approximately proportional to the difference between the reservoir, or static bottom-hole, pressure and the flowing or producing pressure; i.e.:

$$Q = c(p_r - p_{bh}) \qquad [2]$$

p_r = the reservoir pressure,
c = the constant of proportionality.

However, at production rates approaching zero and also at high rates the proportionality may break down. By combining equations 1 and 2 the

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[1] References are at the end of the paper.

production may be expressed as follows:

$$Q = c(\underset{A}{p_r - p_{bh}}) = c(p_r - \underset{B}{hd - p_g} - p_{ch}) \qquad [3]$$

Equation 3 combines the basic theoretical equations, relating the rate of production Q with the bottom-hole pressure p_{bh} and with the fluid level h. It follows from this equation that a graph of experimental values with bottom-hole pressure p_{bh} (portion A) or with fluid-level h (portion B) as ordinate and rate of production Q as abscissa will approach a straight line. Extrapolating this line to the Q intercept, i.e., the value of Q for $h = 0$, yields the *theoretical* maximum rate of production, since $h = 0$ corresponds to a minimum back pressure of the fluid in the hole; where

$$Q_{\max} = c(p_r - p_g - p_{ch}) \qquad [4]$$

As will be illustrated later, this *theoretical* rate may not be achieved in practice, since a definite head is necessary to force the oil to flow into the pump.

The production characteristics of a well may be determined by measuring either the bottom-hole pressure as shown by portion A of the equation or the fluid height h and average gradient d as shown by part B of equation 3. Technically, either set of factors is subject to direct measurement; the type A relationships are directly measurable by means of bottom-hole pressure gauges, while the type B relationships are utilized by measuring the fluid-level height and density of the fluid. For a majority of the fluid-level measurements, the density of the fluid need not be measured, but may be determined indirectly by other relationships, such as that expressed in equation 4.

Bottom-hole Pressure Gauge

The bottom-hole pressure gauges in use at the present time are usually of a self-contained, continuous recording design.[3,4] The gauges are enclosed in a suitable case and consist of two essential parts: (1) a pressure element to record the hydrostatic pressure, and (2) a clock-driven chart drum. A stylus attached to the free end of the pressure element records its movement on sensitized paper or metal affixed to the chart drum. To measure the bottom-hole pressure in a pumping well, the pump is pulled and the gauge is fastened or housed below the pump. The pump is then run back into the hole, and the gauge records the pressure existing in the well at that depth. At the conclusion of a run, the gauge is recovered by again removing the pump. If everything goes well, the record will show the variations in pressure versus the time throughout the test.

The use of bottom-hole pressure gauges in pumping wells necessitates pulling the rods, and at times even the tubing, in order to lower the

instrument into the well. On completion of the measurements the rods are again pulled to recover the instrument, after which the rods and pump are replaced in order to resume the interrupted pumping operations. The recording must be made over a sufficient period of time (72 hr. in some cases) to insure that equilibrium has been reached after the shut-down period preceding installation of the gauge. Upon completion of the test, the data are available within 10 min. or so after the pressure gauge has been recovered at the surface.

The cost of making pressure-gauge measurements varies with the conditions existing at the well. Operating costs on the pulling unit vary from two to three dollars per hour. In California* pay for the crew averages about four dollars an hour. Two full round trips of about 5000 ft. of rods and tubing, at 10 hr. per round trip, costs: crew, $4 per hour; hoist unit, $2 per hour; making a total of $6 per hour.

$$\$6.00 \text{ per hr.} \times 10 \text{ hr.} \times 2 \text{ round trips} = \$120.00$$

If only the rods are pulled, the time required is much less, and the total cost of the two round trips is about $50. To this must be added the cost of maintenance for the pressure gauge and reasonable depreciation on its initial investment.

The initial cost of pressure gauges varies from $600 to $1500, with an additional charge for auxiliary equipment. Calculated on a per diem basis for continuous operation, the cost of maintaining a pressure unit is approximately $10 per day. Since, in general, from two to three days is required to determine the production characteristics of a well, the instrumental cost per well ranges between $20 and $30, and this must be added to the labor costs itemized above.

The pressure gauge sometimes suffers a disadvantage in the time required for each test. Usually 8 hr. or more is required for the "in" and "out" run with a pressure gauge. As already stated, the well must be produced a sufficient period of time to allow equilibrium to take place. This time varies from 8 to 72 hr. The effects on bottom-hole pressures of altering pump speeds, etc., while the gauge is in the well, are not available until after the gauge is recovered. In tests of pump speed, well proration and similar operations, this time delay is often undesirable.

Methods for Determining Fluid Level

Under certain conditions, various types of measuring lines, floats and chalk-line systems may be employed for determining fluid heights. As a general rule, however, such methods are limited to open wells and cannot be successfully employed during pumping operations. The most successful methods for determining fluid levels in pumping wells or wells under pressure operate on sonic or wave-reflection principles.

* Howard C. Pyle, personal communication to the writer.

The parts of the wave method of determining depths to fluid levels comprise: (1) a means for initiating the sound or pressure wave; (2) a

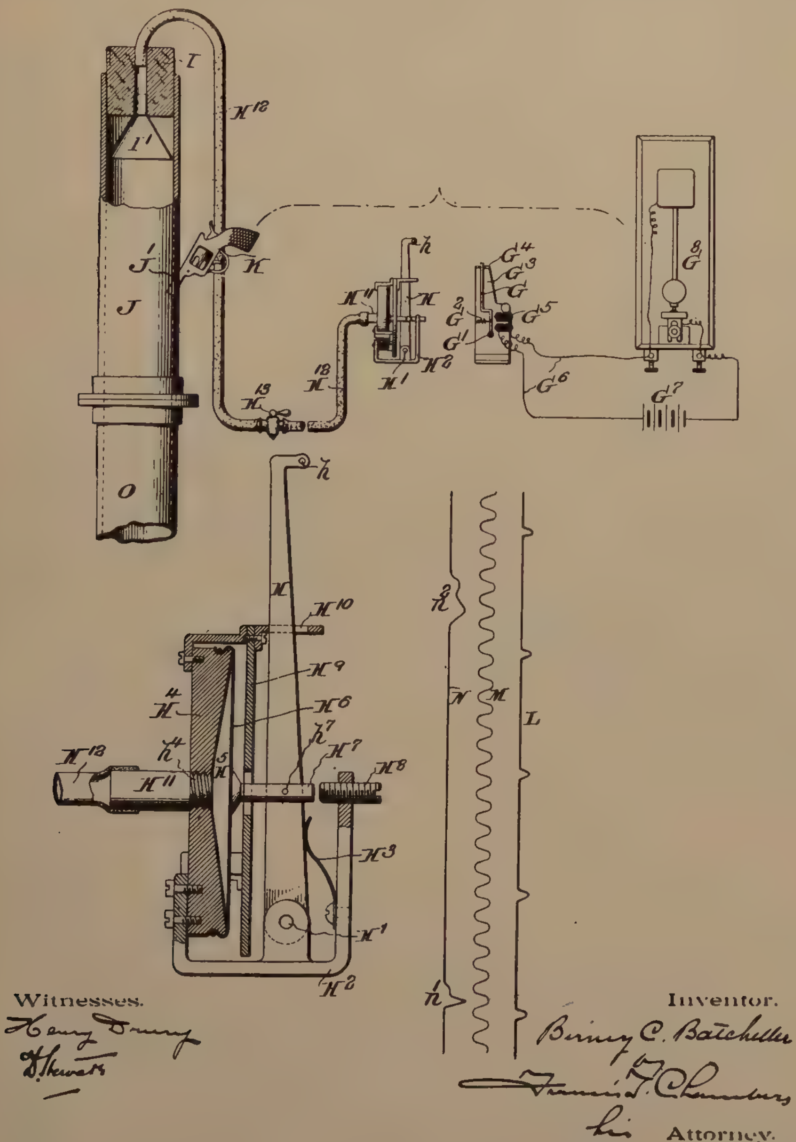

FIG. 1.—BATCHELLER EARLY PATENT COVERING WAVE METHOD OF LOCATING OBSTRUCTIONS.[6]

K, gun for creating wave.
H^{13}, protecting valve.
H^6, diaphragm actuated by waves.
h, stylus for recording motion of diaphragm.

suitable wave-detecting and recording apparatus, and (3) a constant-speed recording system and/or timer.

Considerable work has been done on sonic means of determining fluid levels, and also on sonic or pressure-wave methods for locating obstructions in tubings of various kinds.[5] A commercial incentive for this early work was furnished by the difficulties encountered in operation of the underground pneumatic mail and transport tubes. These tubes were from 6 to 8 in. in diameter and sometimes as long as 15 to 20 miles, with various stations along the route. The material to be transported was placed in a carrier tube and propelled to its destination by compressed air. Often the carrier would become lodged between stations, tying up the entire system. The blocked tubes were found by echo-wave methods. Knowing the point of blocking, excavation from the ground level to the pneumatic tube could be carried out and the blocked carrier removed.

The first practical application of the wave method in the United States probably was made by Batcheller[6] in 1898, who employed the apparatus illustrated in Fig. 1. The Batcheller method utilized a cartridge for initiating the wave. Firing of a cartridge creates complex pressure waves, with the components of higher frequency dying out rapidly with the distance traversed by the wave. This difference in attenuation properties of the components of the wave causes the sonic method as initially suggested by Batcheller to have the disadvantage of interference and reverberation effects, which produce a disturbed record for a brief period of time after the firing of the cartridge.

Efforts to obtain more reliable data than those given by the original Batcheller procedure have yielded two commercial methods: (1) a pressure pulse method, which employs a subaudiofrequency pressure impulse created by the release of compressed gas from a small tank, and (2) the selected frequency steep-front wave method, which employs waves initiated by a cartridge. The first method was developed by Lehr and Wyatt[7] and is essentially similar to that illustrated in Fig. 1 except that the gun used by Batcheller is replaced by gas under pressure. Batcheller's stylus recorder is replaced by a similar diaphragm-driven system, which, however, utilizes photographic recording for greater sensitivity.[8] In this method the energy for creating the sound wave must be of a relatively high level in order that the smaller reflections may have sufficient energy to operate the recording diaphragm. Special precautions must be taken therefore to record these weaker reflections. This is accomplished through acoustical tuning by: (1) setting up a condition of resonance between the collar echoes coming out of the well and an oscillation that takes place in the tuning pipe between the recording instrument and the casinghead, or (2) tuning the diaphragm to the frequency, or a harmonic thereof, of the tubing-collar echoes.

The use of resonant or tuned diaphragm systems is often a source of error, since such undamped devices are usually set into motion by the initial waves and, being undamped, continue to maintain their natural

period regardless of the weaker subsequent reflections. Such tuned devices seldom record the occasional odd lengths of tubing that differ from the "average" length near the top of the well.

Proper utilization of sonic resonance necessitates careful tuning. This step requires considerable time and is a cut-and-try procedure: the wave is created by releasing a pulse of gas from a high-pressure cylinder, and the effects are observed visually; then the tuning is changed and the resultant change, when the wave is again created, is noted. This procedure is repeated until the desired effects are obtained, after which the photographic record is made.

In the second method a steep-front wave is created by use of a special cartridge, and the component frequencies are filtered so that the frequencies utilized in the measurements include only a relatively narrow

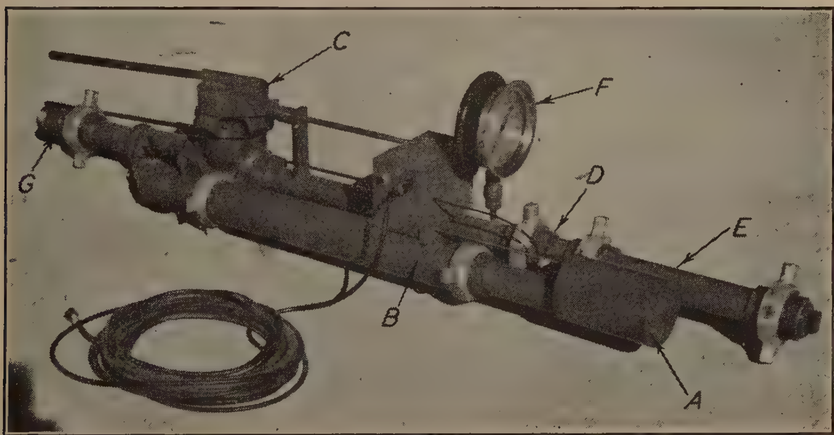

FIG. 2.—ECHO-METER CASINGHEAD UNIT.

A, automatically fired gun.
B, flame arrester and acoustical filter.
C, quick-opening valve.
D, microphone detector.
E, surge chamber.
F, pressure gauge.
G, casinghead connection.

band. The attenuation is relatively constant for the frequency band used. High amplification may be employed without picking up the higher shot frequencies and reverberations, the noises created by the pumping operations, or the low-frequency surges or heading of the fluid in the well. Numerous patents are pending covering Echo-Meter methods and apparatus.

Electrical amplification is employed for recording the reflections picked up by the microphone. Undesirable phase shift in the amplifier is minimized, because of the relatively narrow frequency band employed in the measurements. The mechanical part of the equipment that is attached to the casing head of the well is shown in Fig. 2, and comprises: manual or automatically fired cartridge system *A*; fire trap *B*; manual or motor-controlled interlocking quick-opening valve *C*; detector or microphone *D*; surge chamber *E* and pressure gauge *F*. The unit is connected

to the casinghead by means of a 2-in. nipple, *G*. These units are readily constructed to withstand any desired pressure.

The fire trap quenches the open flame produced by the cartridge and prevents ignition of the gas in the well where the casinghead is open to the atmosphere. The fire trap is designed to acoustically filter out the higher frequency noises, and pass the lower audiofrequencies.

The conventional type of speech microphone does not possess the desired frequency response for use in fluid measurements. The micro-

FIG. 3.—ECHO-METER EQUIPMENT.
Amplifier, automatic volume control and power supply (left), direct writing ink recorder and timer (right).
Lower cabinet contains storage-battery power supply and miscellaneous supplies.

phone employed in the Echo-Meter system has a frequency characteristic from a fraction of a cycle per second declining rapidly to approximately 40 cycles per second.

The output of the microphone is coupled to a high-gain amplifying tube feeding a driver circuit, which is connected to a stage of power amplification. A selector and automatic volume-control circuit allows high amplification to be employed to record the feeble echoes from tubing collars without overloading on the much stronger reflections from the fluid level. This feature successfully eliminates the necessity of accurate acoustic tuning, with a resultant great saving in time at each well. The amplifying and recording equipment faithfully records either negative or positive pressures. A record of the true acoustics is obtained rather than the pretty, but sometimes misleading, sine-wave curve obtained by use of a tuned or resonant system.

The conventional type of photographic recording oscillograph was employed at first for recording the reflections. This, however, necessitated photographic development, with its resultant time delay and inconvenience as regards field operations. Recently, a more rapid and practical type of recording method has been developed, which comprises a direct-writing ink recorder. This recorder employs a continuously moving paper tape passing under an ink stylus, which records the reflections as they are picked up by the microphone. The recorder consists essentially of two electromagnetic drives actuating the recording stylus. Hunting and overshooting of the pen is avoided by proper negative feedback in the amplifier and electromagnetic damping in the recorder. The paper is driven at a constant speed by a synchronous motor operating on the amplified output of an electric tuning fork. The paper, which has the same physical dimensions as the conventional 35-mm. perforated film, is specially prepared to minimize changes in length due to variations in humidity and temperature. An exterior view of the recorder is shown in Fig. 3 at the right, and the amplifier and control unit is shown on the left.

Operation of the Echo-Meter Equipment

The entire Echo-Meter equipment is carried in a light truck. When fluid-level measurements are to be made, the truck is placed within 100 ft. of the well and connected by a shielded cable to the casing-head unit, which is connected directly to the casing head. If the well is under pressure, a valve is placed between the casing head and the unit.

As a preliminary step in operation, the recorder is started and the protecting valve closed except a small hole that is drilled through the valve gate C for recording the initial shot time (Fig. 2). When the cartridge is fired a steep-front sound wave is sent into the casing head and moves down the annular space between the casing and the tubing. The speed of travel varies with the composition and density of the gas; to a slight extent with its temperature, and to a still smaller extent with the effective size of the space between tubing and casing.

As the sound wave travels down the annular space between tubing and casing, it is gradually absorbed and partially reflected by practically all obstructions that change the effective area or opening between the tubing and the casing. Small reflections are generated by tubing collars, while tubing catchers and liner tops usually send back much stronger reflections. The fluid surface reflects practically the whole wave front that has traveled to the bottom of the well. A typical ink record as obtained by the Echo-Meter method is given in Fig. 4. On this record are marked the shot point, various tubing-collar reflections, tubing-catcher and fluid-level reflections.

Dependence of Wave Velocity on Composition and Temperature of Gas

In an *ideal* gas the dependence of the velocity on temperature, pressure and density may be expressed by the formula

$$V = \sqrt{\frac{\gamma P_0}{\rho_0}(1 + \alpha T)} \qquad [5]$$

where V is the velocity, P_0 the pressure and ρ_0 the density at 0° C., α is a constant, T the temperature in degrees Centigrade and γ the ratio of the specific heats.

However, such ideal conditions do not obtain in oil wells, for we are not dealing with wave motion in a true gas but in a mixture of gas and saturated vapors of which the actual composition is not only unknown in most wells but difficult to ascertain. Thus it is not feasible to estimate the velocity of sound from the chemical composition of the gas. The wave velocity in a true gas is constant over a wide range of pressure, while in a gas-vapor mixture there are wide variations in velocity caused by the changes in composition with changes in pressure, as the components of higher vapor pressure condense or vaporize.

Temperature of the gas in a well closely follows the average temperature of the tubing and casing. The temperature gradient is small and usually decreases uniformly from its higher value, at the bottom of the hole, to its lower value at the casing head.

Equation 5 indicates also that in gases of different densities the velocities are inversely as the square roots of the densities. It is found in practice that the highest acoustic velocities are obtained in wells producing gas consisting almost entirely of methane. The velocity of sound in methane is approximately 1400 ft. per sec.[9] Lower velocities are obtained in wells containing heavy, saturated gases, such as rich casinghead gasoline, where velocities are as low as 800 ft. per second.

When work was begun in areas where the wells are open to the atmosphere it was expected that the heterogeneous mixtures of air and gas would have irregular velocities, but very seldom have erratic velocities been observed because: (1) the efflux of gas from the well prevents infiltration of air, and (2) air is lighter than the gas in the well and therefore does not reach appreciable concentrations unless it is mechanically drawn into the well. The latter condition only occasionally takes place where the draw-down is faster than the rate of gas production.

In pumping wells, the true velocity of the wave has been found to be practically constant throughout the entire length of the well, indicating uniform gas composition. The effective velocity, however, is composed of the velocity of sound plus a velocity due to expansion of the gas used for creating the wave. The latter factor will be described in a later paragraph.

Experience in California, Kansas and East Texas now indicates that fluid levels by true velocity calculations may be determined with an error considerably less than 2½ ft. per 1000 ft. in depth.

Determining Fluid-level Depths by Echo-Meter

The depth to the fluid level may be determined by various relationships. In one procedure the true velocity of the wave in gas from the particular well under consideration is determined. The measurements for gas velocity are rapidly made by employing the recording equipment previously described. To the Echo-Meter casing-head unit is connected a known length of high-pressure tubing, arranged, for convenience, in a coil. Gas from the well is allowed to flow through the tubing and casing-head unit until the system is entirely purged of air. The time required for the wave to travel through the tube is recorded, as shown by the calibration run in Fig. 4. Knowing the effective length of tubing and the time, the velocity may be calculated from the simple relation:

$$V = \frac{2D'}{T} \qquad [6]$$

D' is the length of tubing, T the time and V the wave velocity in gas from the well under test.

The depth to the fluid then may be calculated by applying formula 6 again. For the case at hand, formula 6 may be written:

$$D = \frac{TV}{2} \qquad [6a]$$

wherein D is the depth to the fluid level in feet; V equals the true velocity in feet per second of the wave; T is the time in seconds required for the wave to travel to and from the *fluid surface*. As will be noted by reference to equation 5, the effects of variations in temperature of the gas are relatively unimportant for the small changes that ordinarily occur in any particular well, and therefore may be neglected in practical measurements.

After determining the true velocity as described later, the depth to fluid may be determined by the simple proportion:

$$\frac{\text{Length of calibration record}}{\text{Corrected length of fluid-level record}} = \frac{\text{Length of calibration pipe in feet}}{\text{Depth of fluid in feet}}$$

In another procedure, applicable only when the well records show the total length of tubing and the number of joints, the average joint length may be calculated by dividing the number of joints into the total length. In the well under consideration, the calculations gave an average length of 20.58 ft. (range 1 tubing). Knowing this average length, the fluid level may be calculated from measurements taken directly from the Echo-

Meter record. Thus in Fig. 4 the record length S_1, with its known number of tubing reflections, is compared to the distances S_2 and S_3. This relationship or proportion is expressed in the following equation:

$$\frac{D}{S_3} = \frac{nl}{S_1} \quad \text{or} \quad D = \frac{S_3 nL}{S_1} \tag{7}$$

wherein D = the depth to fluid level, ft.,
S_3 = the distance to the fluid-level reflections, mm.,
S_1 = the distance corresponding to a definite number n of tubing reflections, mm.,
L = the average joint length as obtained from the calibration run or the well records.

The depth to the fluid level for the well data shown in Fig. 4 is determined by substitution in equation 7 as follows:

Average length of tubing joints	20.58 ft.
Number of joints counted	52
Measured record distance for 52 joints	332 mm.
Measured record distance for fluid-level reflection	419 mm.

$$\text{Depth to catcher} = \frac{411 \times 52 \times 20.58}{332} = 1325 \text{ ft.}$$

$$\text{Depth to fluid} = \frac{419 \times 52 \times 20.58}{332} = 1350 \text{ ft.}$$

Another procedure may be employed (after correcting for "apparent velocity") in wells where the tubing catcher or an artificial reflector is placed at a known depth. In such cases the calculations are somewhat simplified, since the depth is determined by comparing the reflection at a known depth with the fluid-level reflection. As an illustration, if the depth to the tubing catcher in Fig. 4 could be taken directly from well records, the fluid level would be determined by simple proportion as follows:

$$\frac{411 \text{ mm. (to catcher)}}{1325 \text{ ft.}} = \frac{419 \text{ mm. (to fluid)}}{\text{Fluid depth}}$$

$$\text{Fluid depth} = \frac{1325 \times 419}{411} = 1350 \text{ ft.}$$

In the well for which these figures were obtained the pump was at a depth of 1930 ft., hence the height of the fluid column was 1930 − 1350 = 580 feet.

The well was pumping at a casing-head pressure of 38 lb. per sq. in. and was producing 8 per cent water, which readily separated from the oil by gravity. The specific gravity of the oil was 0.831. Using equation 1 and neglecting the weight of the gas column p_g, the bottom-hole pressure at the pump may be calculated as follows:

$$\begin{aligned} p_{bh} &= (580 \times 0.831 \times 0.433) + (38 + 14.7) \\ &= 208.7 + 52.7 = 261.4 \text{ lb. per sq. in. absolute} \end{aligned}$$

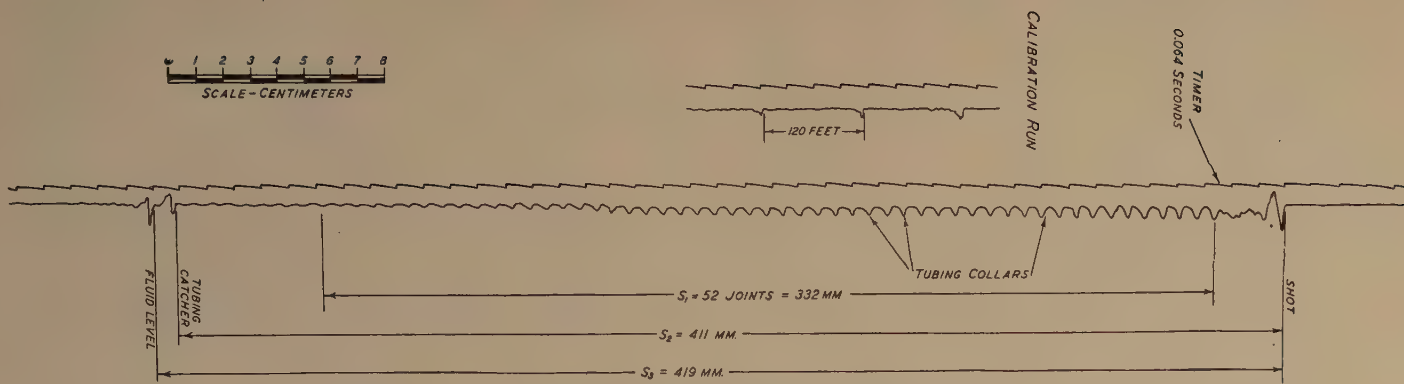

FIG. 4.—TYPICAL ECHO-METER RECORD.
a. Calibration run to determine actual gas velocity and tubing joint lengths.
b. Fluid-level measurement to determine depth to fluid and other well obstructions.

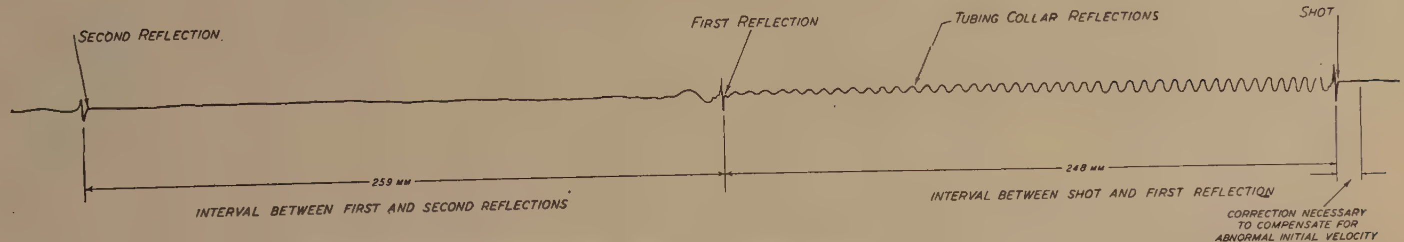

FIG. 5.—VARIATIONS IN TIME INTERVAL BETWEEN FIRST AND SUBSEQUENT REFLECTIONS, DUE TO CHANGE IN VELOCITY.

Corrections for Abnormal Initial Velocities

When the wave is initiated either by the release of confined high-pressure gas or by the firing of a shot, a certain volume of gas is released into the casinghead. This gas expands and travels down the annulus with an initially high velocity, which gradually decreases as the pressure of the gas is reduced by its expansion in the annulus. This velocity of the expanding gas is superimposed on the velocity of the wave motion in the gas, resulting in an abnormally high velocity at the initiation of the wave. If uncorrected, this abnormal "apparent velocity" introduces an error,

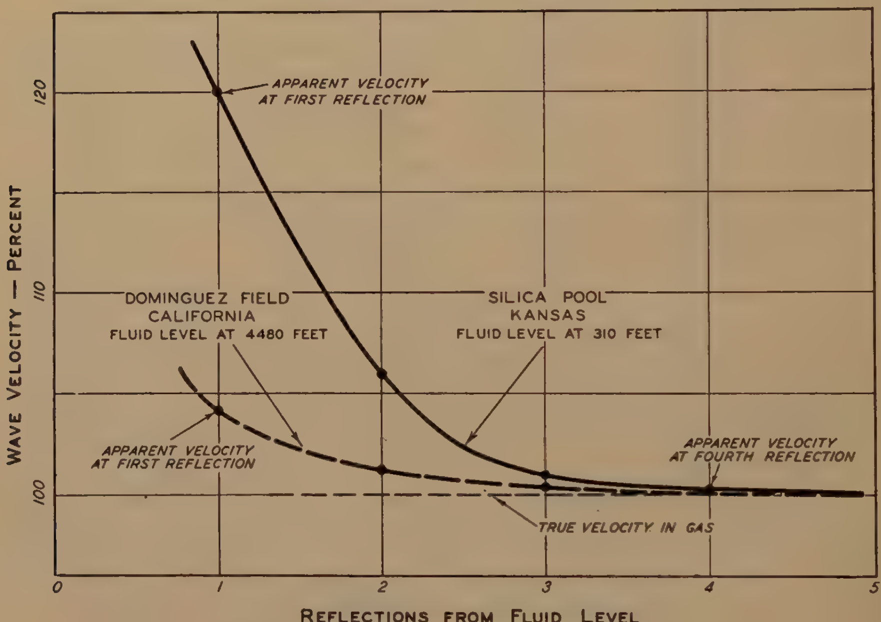

FIG. 6.—CHANGE IN APPARENT VELOCITY.

with a resultant erroneously high fluid level. This abnormally high component of the velocity is dependent upon: (1) the volume of gas generated by the shot or injected in the pressure pulse; (2) the cross-sectional area of the annulus in the upper portion of the well, (3) the relative wave velocities in the original gas of the well and in the injected gas, and (4) the casing-head pressure of the well. This error in the velocity often is less when a quick detonating cartridge is utilized for creating the wave than when a quantity of low-pressure gas is released from a container; probably because: (1) less energy need be employed, owing to the steep wave front generated by the cartridge, and (2) a lower effective volume of gas is injected into the casing head, owing to the rapid cooling of the hot gas by the flame arrester.

The error in measurement due to the expansion of the gas may be corrected by comparing the time interval for the first reflection with the intervals for second and subsequent reflections. This correction is illustrated in Figs. 5 and 6. The time interval between the initiation of the wave and the first fluid-level reflection is less than the time interval between the first and the second reflections, and so forth. In practice, the Echo-Meter records are taken to show the first two or more fluid-level reflections, from which the correction factor may be determined. Errors due to this apparent velocity are minimized when measurements are made in wells having a definite marker near the fluid level or where reliable tubing-collar reflections can be obtained throughout the entire record.

By proper adjustment of the electrical amplification working in conjunction with an amplitude control, the tubing-collar reflections and other minor reflections are clearly defined in the portion of the record between the shot and the first reflection, while the fluid reflection is most clearly shown in the subsequent reflections, because of the greater attenuation of the tubing-collar reflections. A single shot therefore serves: (1) to show clearly tubing-collar reflections, (2) to correct for the abnormal velocities present immediately after initiation of the wave, and (3) to give the true fluid-level reflection time.

Operating Economics

When making simple fluid-level measurements, from 12 to 18 wells may be measured and computed in an average day's operation at a cost of about $3 per well. When making production-potential measurements, which comprise fluid-level measurements at a static and two or three pumping speeds, the time required per well depends chiefly on the time necessary for equilibrium conditions to be reached between the different pumping rates. When feasible to shoot a number of wells in rotation to allow equilibrium to be reached in one well while making the measurements in another, three to four complete well prorations may be taken in a day. Limited tank-gauging facilities may also retard the speed of the measurements, usually due to the inability of disposing of the run oil because of proration restrictions. The cost of prorating a well by making fluid-level measurements at three rates of production is approximately $20 where four or more wells can be measured in the same field to allow rotation of measurements while the wells reach equilibrium between measurements.

Effect of Fluid Density on Bottom-hole Pressure Determinations

Equation 3*A* shows that the average density of the fluid is not required for the pressure-gauge measurements, since that instrument directly records the actual pressure existing at that particular depth. The

accuracy of bottom-hole pressure calculations from fluid-level measurements is dependent on the accuracy with which the average density of the fluid may be determined. In the work in California, central Texas and western Kansas, the pressure-bomb and the fluid-level results are consistently in agreement within a few per cent, which is within the limits of accuracy of the component steps in a proration measurement.

Occasionally in areas where large variations occur in the oil-water ratio, the accuracy of the fluid-level measurements may be impaired by the errors that usually occur in determining fluid density. At all pumping rates where an appreciable draw-down of fluid is obtained, however, the errors are minimized and nearly always are negligible for all practical considerations. Under such conditions, the most reliable data will be obtained in draw-down tests when adequate tank capacity is available to allow proper gauging for determining the proportion of oil, bottom settlings and water. If grind-out samples are taken, they must be representative of the flow stream, with proper proportioning of the sample volume to the total volume of fluid per unit time. Automatic sampling devices are preferred to the occasional hand sampling methods.

In a great majority of fields, an appreciable separation of water from the oil takes place in the annulus, which therefore is filled with clean oil rather than with the gas-oil-water mixture produced by the formation. Under these conditions, the hydrostatic head is equal to the product of the height of the fluid column times the density of the *oil*, which will be evident from the following considerations:

When wells of high productivity are pumped at rates considerably less than their potential, a separation of the fluid into its components obtains when equilibrium is reached. The effects of this gravitational separation are illustrated in Fig. 7. Since the pump is removing the fluid at the same rate it is flowing into the well, which is the condition obtaining when the fluid level is stationary, the fluid below the producing horizon is essentially of the same composition as that leaving the formation. In the annulus above the producing horizon, where direct flow of fluid from the formation is not taking place, a quiescent fluid condition exists, which permits gravitational separation of the fluid. The free oil is in the upper portion of the fluid column, while the bottom settlings and water are in the lower part of the column. The degree to which this separation takes place will be chiefly dependent upon: (1) time during which equilibrium has existed, and (2) the stability of the oil-water mixture in that particular well. In wells where the oil and water are readily separated by gravity, the water and much of the bottom settlings will be carried away by the moving fluid stream. Under such conditions, the density of the fluid in the column will be substantially the same as the density of the clean oil. Therefore the density of the oil is used for the calculations rather than the density of the fluid being pumped from the well.

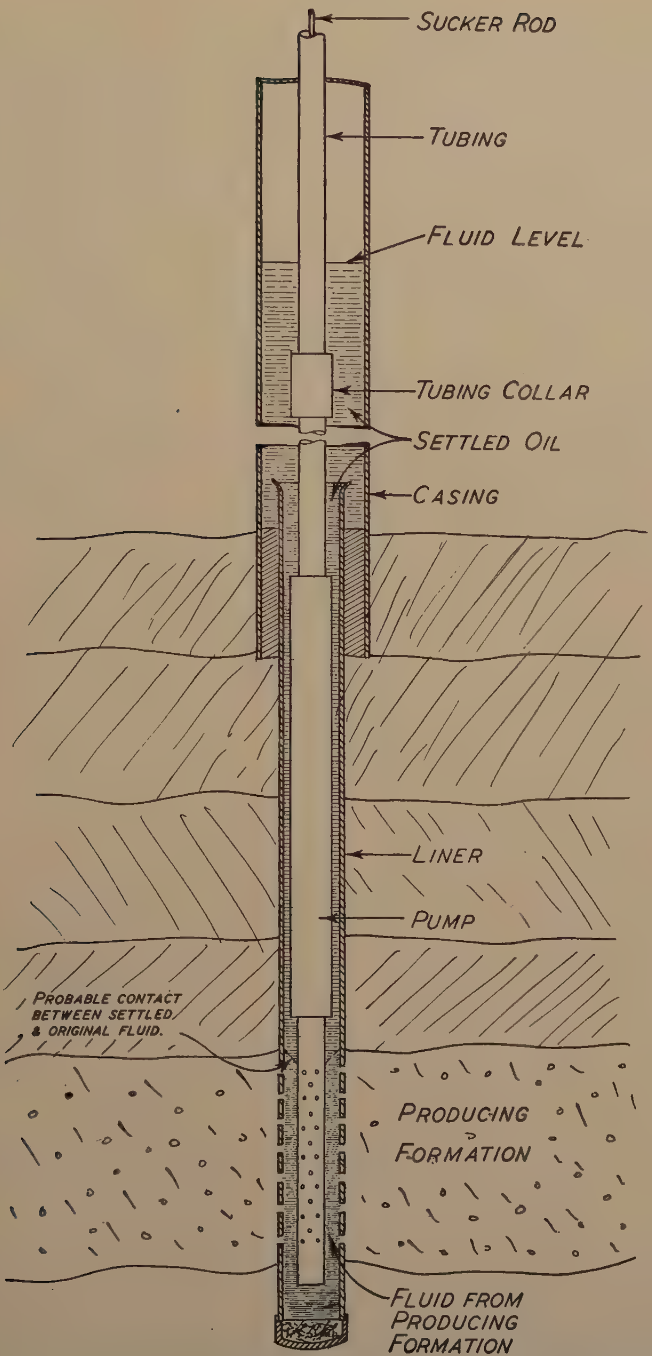

FIG. 7.—ILLUSTRATION OF GRAVITATIONAL SEPARATION OF OIL FROM FLUID PRODUCED BY A WELL.

When conducting fluid-level measurements in wells where large amounts of water are produced, it is advisable to allow equilibrium conditions to be established a given interval of time before making the measurements, in order that gravitational separation of the fluid in the annulus may take place. In wells where the oil and water separate with difficulty, this interval of time may be measured in many hours. Experience in a given field is usually the best criterion. Measurements should be made at the highest fluid level first, followed by the progressively lower fluid-level measurements.

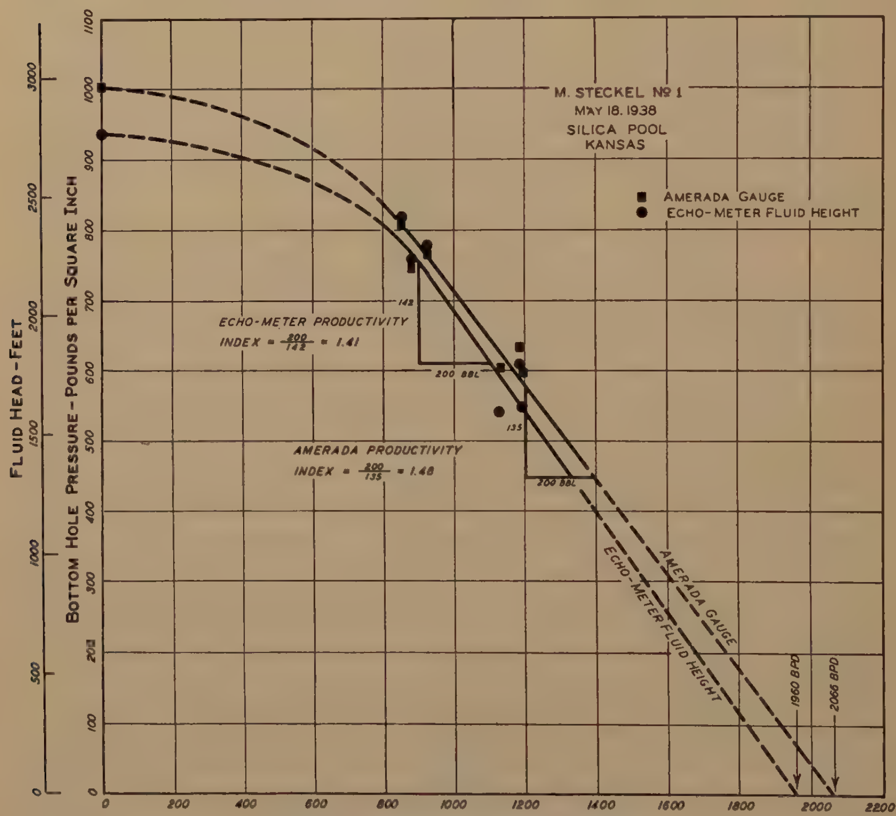

FIG. 8.—DETERMINING WELL PRODUCTIVITY BY FLUID-LEVEL AND PRESSURE-GAUGE MEASUREMENTS.

Solution of Pumping Problems

Fluid Level in Pumping Wells.—Single fluid-level measurements will immediately supply information that will allow an operator to ascertain whether a well is pumping off or is gas-locked. Often it is impossible to tell by the pounding on the polished rod which condition exists in a well. Pounding due to pumping off is caused by a low fluid level or by the

pump being set too high in the well, while the pounding due to gas-locking may occur when a high fluid level exists above the pump.

Determining Pumping Rates and Well Productivity.—The most important producing characteristics of a well may be determined by making

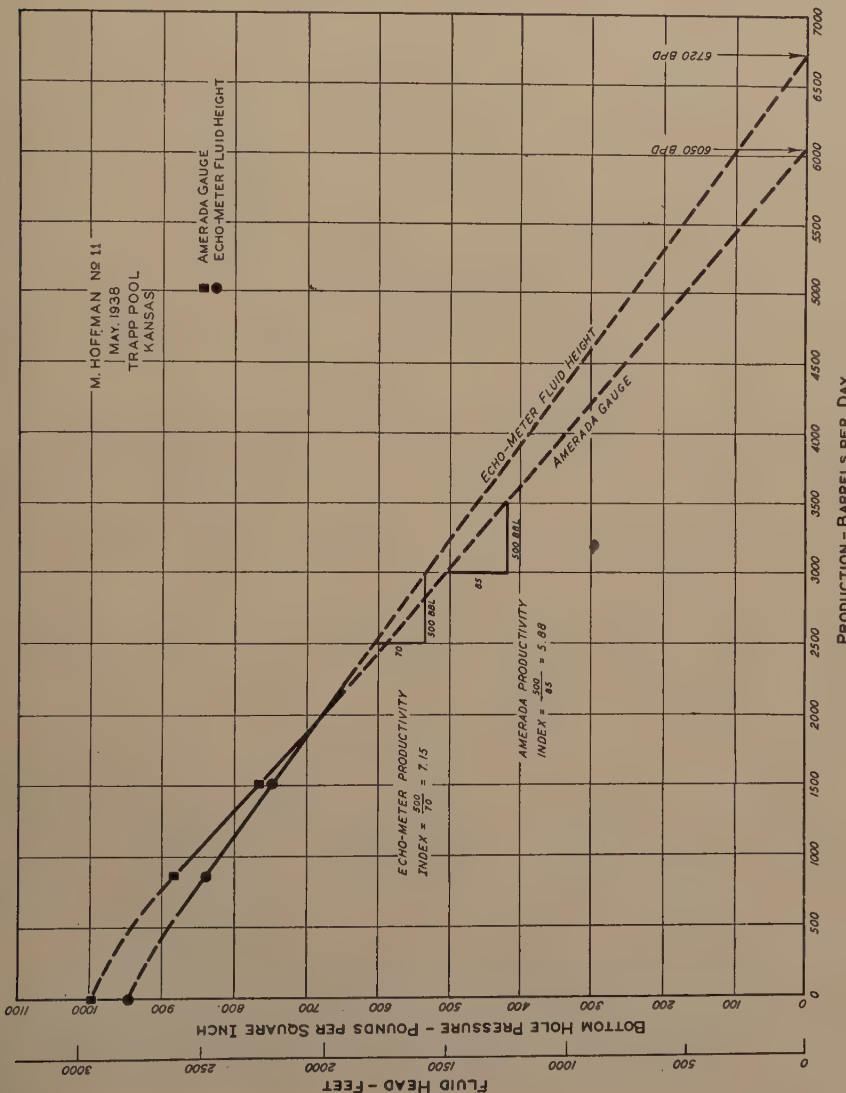

FIG. 9.—DETERMINING WELL PRODUCTIVITY BY FLUID-LEVEL AND PRESSURE-GAUGE MEASUREMENTS.

use of the relationships given in equations 3 and 4. The bottom-hole pressures or fluid heads are determined at two or more production rates, and plotted as shown in Figs. 8 and 9. Extrapolating the curve to the Q intercept gives the theoretical maximum production of which the well

is capable, on the assumption that flow friction, water coning or other variables encountered in practice will not change the slope of the curve. This maximum production figure is the theoretical potential for the well. It is obtained without expensive physical pumping tests and eliminates entirely the dangers of water coning, mechanical damage to pumping equipment, etc., so prevalent in the physical pumping tests for determining well potentials.

Fluid-level measurements recently have been made a legal means of proration for wells in certain fields of Kansas. Similar legislation is being enacted by other states. It is estimated by operators in the Bemis pool, Kansas, that the pump draw-down method of proration cost approximately $1000 per well, as compared to the present cost of about $20 for proration by fluid-level measurements. From an investment viewpoint, the bottom-hole pressure or fluid-level measurements also save the great costs of large pumping installations, which are still used in some fields for determining well potentials by actual physical pumping tests.

The productivity index is the slope of the productivity curve, and is defined as "the barrels per day of gross liquid produced per pound per square inch pressure drop at a specified subsurface datum."[10]

Any condition tending to change the productive capacity of the well is indicated by a change in the productivity index or slope of the curve.[2,11,12] A decreasing productivity will be obtained when the gross production per pound drop in bottom-hole pressure decreases. This condition may be caused by increasing water or a decreasing gas-oil ratio, a decrease in effective permeability of the oil formation adjacent the well, or by drainage interference from offset wells. In some places an increased productivity factor may be obtained, especially if the well is cleaning out or channeling. Periodic measurements of this type are a vital necessity in keeping a close check on a well's performance. The decline of a well's potential and its proper pumping conditions can be followed intelligently and often controlled by the use of bottom-hole pressure or fluid-level data.

Fluid-density Determinations.—The determination of fluid density in wells producing with a high gas-oil ratio is illustrated by the fluid-level data for a well in the Dominguez field, California (Table 1).

TABLE 1.—*Fluid-level Data for a Well in Dominguez Field*

Casing-head Pressure, Lb. per Sq. In. Abs.	Fluid Level, Ft.	Change in Casing-head Pressure	Change in Fluid Level
24.7	2990	18	195
42.7	3185	32	220
74.7	3405	81	550
155.7	3995		

The average density of the fluid is obtained by dividing the change in pressure by the corresponding change in fluid level under equilibrium conditions. Owing to changes in solubility of the gas in the oil and also the change in volume of the gas with a change in pressure, the fluid den-

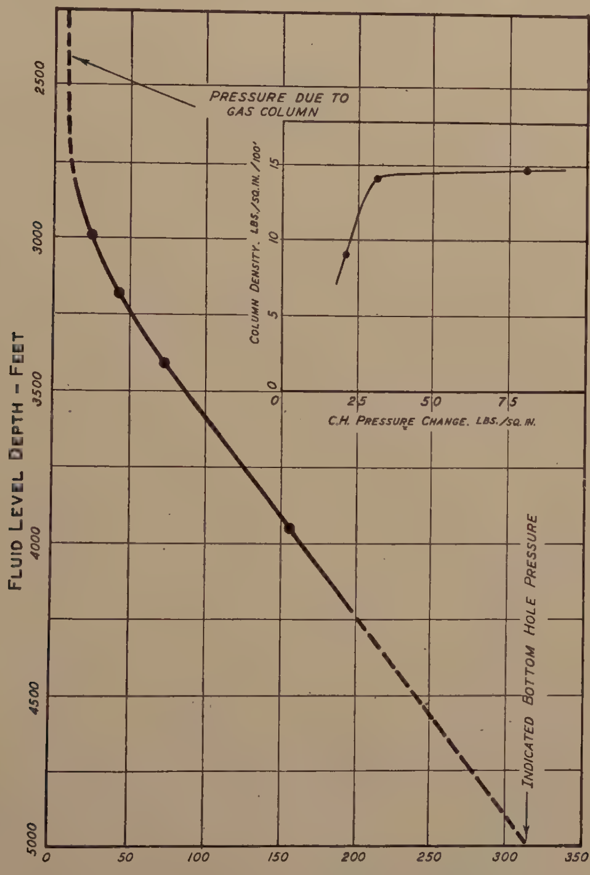

FIG. 10.—DETERMINING FORMATION PRESSURE BY FLUID-LEVEL MEASUREMENTS. INSERT SHOWS VARIATION OF FLUID DENSITY WITH PRESSURE.

sity varies from a maximum value at the bottom of the column to a minimum value at the top of the column. By analyzing the first fluid-level determination, it will be seen that an increase of 18 lb. in gauge pressure depressed the fluid level 195 ft., which is equivalent to a column density of 9.2 lb. per sq. in. per 100 ft. of fluid height; i.e.,

$$\frac{18 \text{ lb.}}{195 \text{ ft.}} = \frac{9.2 \text{ lb.}}{100 \text{ ft.}}$$

The next pressure increase of 32 lb. depressed the liquid about 220 ft., indicating a density of approximately 14.5 lb. per sq. in. per 100 ft. The

following 81-lb. increase forced the level down 550 ft., giving a density of 14.75 lb. per sq. in. per 100 ft. These calculations indicate that above 42.7 lb. per sq. in. abs. pressure the fluid density in this particular well changes slowly and for most practical purposes can be extrapolated down to the pump (see insert in Fig. 10). A density of 14.75 is not abnormal in wells making a fair amount of gas. Solid gas-free fluid in this well would have a density of about 35 lb. per sq. in. per 100 ft.

Determination of Formation Pressure.—The original bottom-hole pressure and its rate of decline as the well produces are of considerable importance. These data may be obtained by use of bottom-hole gauges or by fluid-level determinations in which fluid heights at different casing-head pressures are measured. The analytical procedure for the latter case may be indicated briefly as follows: From equation $3B$, it is evident that a graph of fluid-level data with h as ordinate and casing-head pressure p_{ch} as abscissa approaches a straight line provided the rate of production Q is held constant, since it is assumed that p_r is constant and p_g varies only slightly. Hence, the pressure at the reservoir, p_r, may be obtained by extrapolation to the p_{ch} intercept; i.e., the depth to the producing formation.

The determination of the pressure at the reservoir for the well cited above is illustrated in Fig. 10, which is a plot of the fluid-level versus the total casing-head pressure. (The weight of the gas column is neglected.) This graph indicates that the pressure at the pump is about 315 lb. per square inch.

Maximum Pumping Efficiencies.—For the maximum rate of recovery, the bottom-hole pressure should be reduced as much as possible, and this can be achieved by maintaining the lowest practical fluid level. In actual pumping operations, it is not possible to obtain the full theoretical production rate because of the hydrostatic head that must be maintained in order to feed the oil into the pump. Among the factors on which this head depends are viscosity of the oil, pump speed and capacity and valve design on pump intake. In the fields of western Kansas the differential pressure heads listed in Table 2 have been recommended.

TABLE 2.—*Differential Pressure Heads*[a]

Production, Bbl. per Day	Fluid Level to Be Maintained above Pump for Optimum Recovery, Ft.
250	10
500	19.5
1000	36.0
1500	50.0
2000	63.0
2500	74.0
3000	84.0

[a] Data supplied through the courtesy of Mr. J. H. Miller, Cities Service Co., Great Bend, Kansas.

After making changes in pump speed or capacity, it is advisable to run a fluid-level measurement, to be certain that the proper draw-down is being obtained.

Evaluation Studies

Considerable use is being made of fluid-level measurements for determining subsurface conditions in producing fields. Isobaric maps showing lines of equal bottom-hole pressure are plotted, usually expressed with reference to a common datum plane. Two sets of contours usually are plotted, showing: (1) shut-in fluid levels (static) and (2) pumping equilibrium fluid levels at some given rate of production. These isobar maps give vital information on areas of higher permeability in the field and make it possible for development work to be done in a better engineering manner. This phase of the work is becoming important in connection with the various regulatory measures and trend toward unit control in recent legislation.

Efficiency of Gas Lifts

A recent application of fluid-level measurements in East Texas is in connection with existing or projected gas-lift installations.[13] If a well is being converted from pumping to gas lift, it is convenient to be able to obtain the fluid level in the annular space in advance of the pulling job. Also, the draw-down at various pumping rates will give valuable information regarding the size of valve to be installed. After the installation is completed, its operation can readily be checked quickly and conveniently by fluid-level observations. If it is suspected that a valve is sticking, a close check of the fluid-level variation when the well begins to unload will show which valve is kicking off.

In wells where insert valves of the conventional type are used, it is impossible to run a bottom-hole pressure bomb because the valves obstruct the tubing. In all gas-lift work the Echo-Meter measurements have the additional advantage that the fluid level can be watched continually and the input pressure properly regulated, whereas with the bomb gas can blow through the bottom perforations without the occurrence becoming evident until the run is finished and the bomb recovered.

Acknowledgments

The results described in this paper have been made possible through the kind cooperation of many engineers and companies. In particular, special thanks are due H. C. Pyle, Union Oil Co., Los Angeles, Calif.; D. R. Knowlton and J. S. Montgomery, Phillips Petroleum Co., Bartlesville, Okla.; H. E. Zoller, J. M. Wanemacher, and Henry Keplinger, Shell Oil Co., Wichita, Kansas; D. H. Crall and H. Watters, Stanolind

Oil and Gas Co., Tulsa, Okla.; Marshall Brown and Ray Streight, W. I. Southern, Inc., Tulsa, Okla.; J. N. Miller, Cities Service Co., Great Bend, Kansas; R. S. Knappen, Gulf Oil Co., Tulsa, Okla.; R. E. Reistle and J. M. Huber, Humble Oil and Refining Co., Houston, Texas.

The work of the writer's associates in development of the method and the accompanying field work is acknowledged, with special reference to Messrs. S. Bertram, R. E. Martin, D. D. Taylor, Daniel Elam, R. W. Cornes, F. N. Liscum, and Dr. Florence Ehrenkranz.

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Exploring Drill Holes by Sample-taking Bullets

By Eugene G. Leonardon,* Member A.I.M.E. and D. C. McCann*

(New York Meeting, February, 1939)

The search for oil has required, and without a doubt supplies, a tremendous amount of information on the structure, composition, physical properties, and history of sedimentary rocks. The earliest and most complete source of knowledge is the sample or core of the rock itself, the uses of which are well known. The purpose of this paper is primarily to discuss a new method for obtaining these cores, and to illustrate its use in connection with electrical logs.

Most cores have been obtained through a special adaptation of rotary drilling, and the results have been remarkably good, considering the mechanical problems involved. Unfortunately, because of the time and expense, this method cannot be used for the entire length of the drill hole. Even though ingenious contrivances have been evolved in order to reduce the time spent in round trips, such as wire-line coring equipment, mechanical coring still remains too expensive to be carried out continuously. In practice, therefore, one is finally compelled to estimate the probable depths of the more interesting horizons and, allowing a wide margin of safety, to core through those sections only. It is true also that interesting results have been obtained by examining the cuttings brought to the surface by the mud circulated in the well during the process of drilling. Be that as it may, the inescapable fact remains that key horizons may be passed inadvertently, for one reason or another, while the drilling operations are being performed. The only continuous record of the formations encountered is that furnished by electrical surveys.

Obviously, it would be desirable to make the electrical survey first and to take the samples from the wall of the hole according to the indications on the electrical log. In this way, it would be possible to core only the exact sections desired, eliminating the otherwise inevitable estimates as to the point at which to start coring, and thereby reducing to a minimum this expensive operation. At the same time this method would provide a maximum of useful samples.

A device for taking samples of the formation from the walls of a hole therefore offers the possibility of recovering cores from zones otherwise lost as a source of this type of information. Furthermore, by coring

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* Schlumberger Well Surveying Corporation, Houston, Texas.

according to the electrical log of the well, this method offers a logical and practical system, free from all estimates concerning the number and position of important formations.

A practical means for obtaining these side-wall cores has been developed, and during the past two years this device has been progressively used not only to supplement the mechanical cores but also to provide the entire core record. In addition to supplying information that is available in no other way, the side-wall coring device involves far less time and expense.

Instrument and Methods

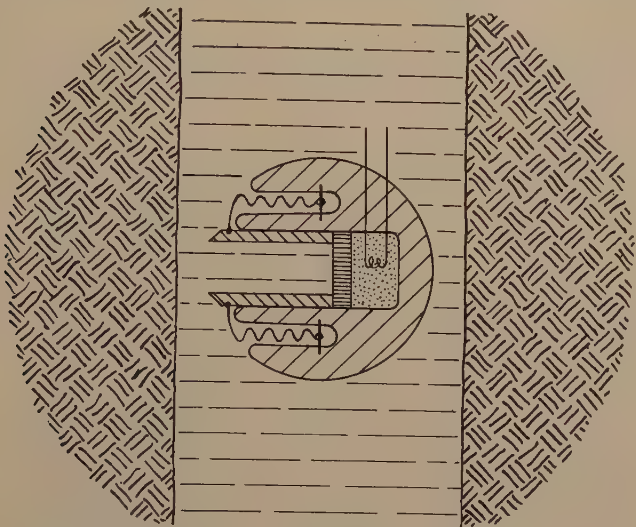
The side-wall sample taker used by us is designed to be lowered into the drill hole by the same cable used for electrical logging. Electrodes are placed on this cable at a fixed distance and very near the sample taker, by means of which a portion of the hole to be cored is electrically surveyed or resurveyed. The points from which samples are to be obtained are marked on this log, the mechanical relation between the log, cable, depth and formation remaining undisturbed. The sample taker is then placed in position by means of this log. In other words, the samples are taken with great accuracy in respect to the formations as they show up on the electrical log, and, in a sense, irrespective of absolute depth.

The principle of the side-wall sample taker (Fig. 1) is relatively simple, and is similar to that of the gun perforator. The bullet, which is fired into the formation by means of a powder charge, is a hollow cylinder, which serves as the core barrel. This bullet is attached to the gun barrel and housing by two lengths of wire, and the housing in turn is attached to the supporting cable. Thus, by applying a tension to the cable, the bullet may be pulled from the formation. The powder charge is ignited by means of an electrically heated wire.

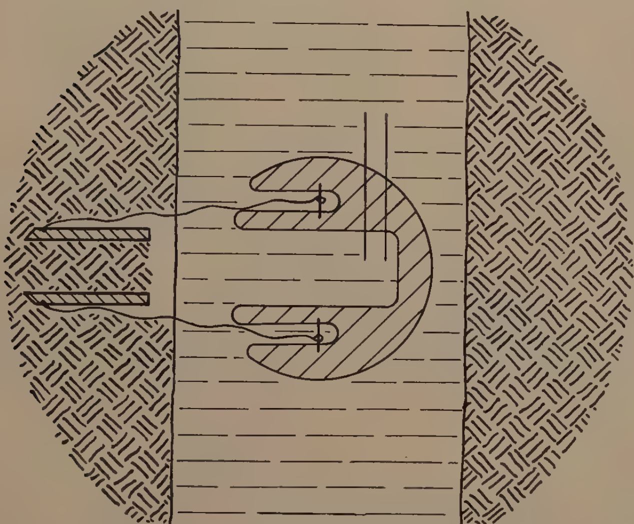
The practical application, of course, requires numerous refinements. For example, the cylindrical bullet must be closed at the bottom before and during the firing, not only to keep the powder dry but also to provide a point of application for the force of the exploding gases. However, if the bullet, after firing, remains closed at one end, and of course full of drilling mud, it may not be filled with appreciable amounts of the solid formation. Consequently, the bottom is not attached to the bullet, so that only the hollow cylinder, open at both ends, penetrates the formation. In this way, not only the drilling fluid, but also the mud cake on the wall of the hole, is passed completely through the bullet, and the sample obtained is that of the formation at the point where the bullet stops. The sample is thus taken from the rock several inches away from the wall of the hole.

Instead of a device capable of securing only one core for each trip into the hole, the practical application consists of a housing for 6 or for

18 bullets (Figs. 2 and 3). Each bullet is fired separately, and at the point that is to be cored. By such means, it is possible to recover as many as 18 cores, all from different horizons, within a period of 3 hr. or



A-Loaded and in Firing Position.



B-Bullet fired into Formation.

FIG. 1.—SCHEMATIC DIAGRAM OF SAMPLE TAKER.

less, depending on the depth. In addition, each gun is quickly interchangeable on the cable, by means of a threaded joint, so that no time is lost if more than one complete gun is necessary.

The Cores

The cores are ¾ in. in diameter and from 1½ to 2½ in. long, depending on the bullet used. Such cores are ample in size for the usual porosity, permeability, and other analyses. Because of the construction of the bullet, or core barrel, there is no compaction or crushing of the core. This is perhaps best illustrated by the photograph of a core that con-

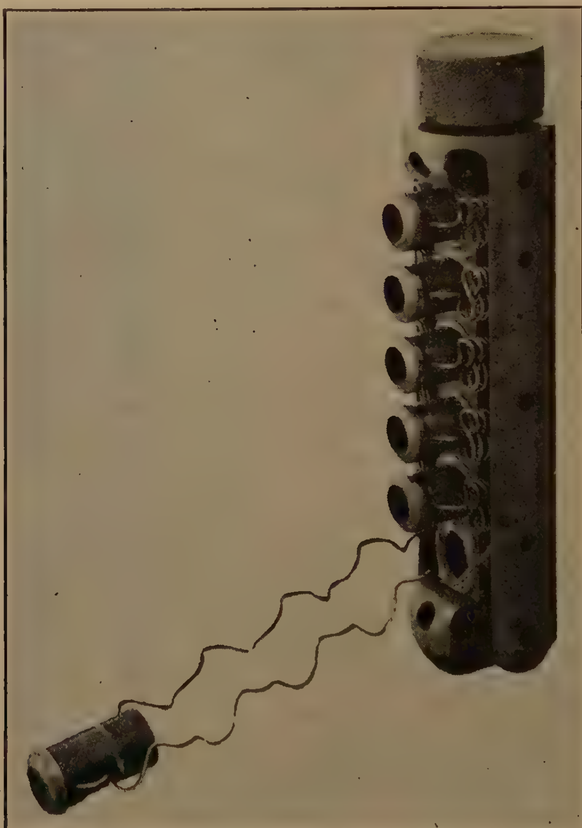


Fig. 2.—Six-barrel side-wall sample taker. The first bullet has been shot.

tained seams of coal (Fig. 4). The bedding is clearly shown, and entirely undisturbed.

The fluid content of cores from porous formations is representative of the original conditions prior to penetration of the formations by the drill hole. No core, mechanical or otherwise, can escape the washing effect of drilling mud. The core cut by rotary methods is seriously affected by the high-pressure circulating mud. Electrical surveys and production tests prove that the porous formations surrounding a drill hole are some-

what invaded by the drilling fluid. The side-wall sample operations have shown that, while this invasion takes place, a true oil sand retains much of its oil, even very near the hole, and a salt-water sand retains much of its salt. The side-wall samples apparently have the distinct advantage of being affected only by the mud under its hydrostatic pressure, while the rotary cores are subjected to the mud under not only the hydrostatic but also the pump pressure.

FIG. 3.—EIGHTEEN-BARREL SAMPLE TAKER.

Efficiency and Safety

The efficiency of the side-wall sample taker, like the rotary method, is not 100 per cent, but the recovery, as compared to bullets fired, is at present about 70 per cent. In general, the 18-shot gun may be expected to return 12 to 15 cores, and this loss of a few cores is relatively unimportant, both because another attempt is always possible, and because the method is extremely rapid.

The side-wall coring device has an excellent record in regard to safety. Very few guns have been lost in a hole of sufficient diameter to permit passage of the gun with the bullets fired. This minimum diameter is 5 in. Numerous tests have been made in holes of smaller diameter, but the practice cannot be recommended. Loss of the gun is avoided by the use of bullet-retrieving wires that have a breaking tension considerably less than that of the cable. If a bullet cannot be recovered, the wires break at the bullet, leaving it in the formation. Even though this occurs, only about 2 per cent of the bullets are lost, and nothing is ever left in the hole.

Field Application

Although electrical logging provides, at a reasonable cost, a continuous record of the entire hole, this record is representative of physical and chemical properties of the formations and must be translated into concrete terms dealing with the constitution of the rocks and their fluid content. Occasionally, certain portions of this log are difficult to interpret because there is not always an

unequivocal correspondence between physical measurements and the geological, lithological, and other characteristics. Moreover, the operator may desire to obtain actual samples for analysis of porosity, saturation, and other data. The side-wall sample taker finds its natural use in obtaining these cores.

At present, the usual object of a sampling operation is the verification of oil, gas, and water zones as indicated by the electrical resistivity. Fig. 5 shows an example. The high resistivity between 6212 and 6220

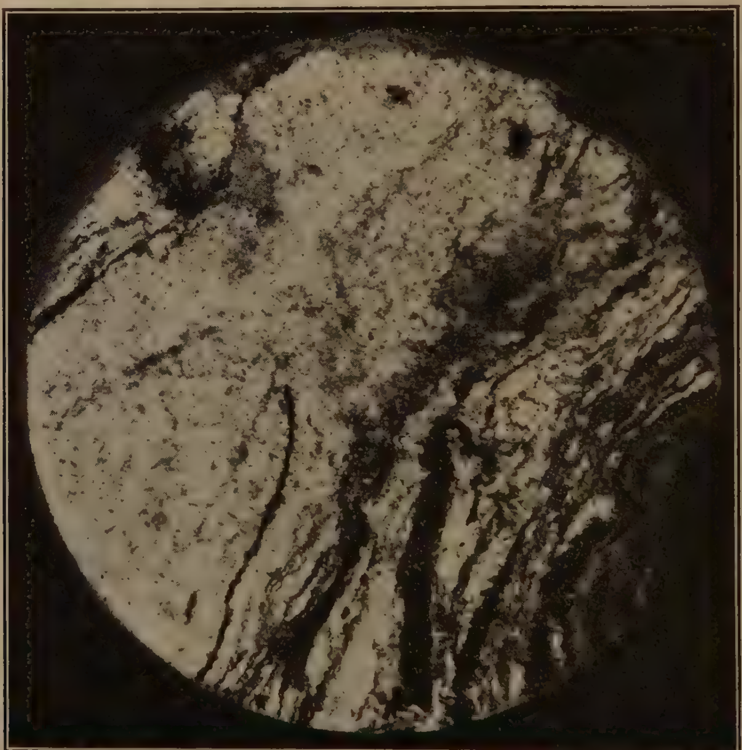


FIG. 4.—SIDE-WALL CORE TAKEN WITH SAMPLE-TAKING BULLET. × 4. Showing coal seams in limestone formation.

ft. indicates oil or gas, while the lower zone from 6220 to 6234 ft. indicates oil or possibly water. The very low resistivity below 6234 ft. is almost certainly due to water. However, it may be very desirable to verify the position of the water and to determine whether the resistant zones are oil, gas, or both. For this purpose, samples were taken at intervals across each electrical boundary. They definitely proved that the sand from 6238 to 6255 ft. was water-bearing, and showed that both the medium and highly resistant zones were oil-bearing.

Very closely connected with the foregoing is the example of Fig. 6. A porous bed has been traversed between 6704 and 6714 ft., but the

resistivity is so low that there is a reasonable doubt as to whether the stratum is water-bearing or oil-bearing, especially in the portion from 6710 to 6714 ft. In the same well, another bed, of similar appearance, has been drilled at 6948 to 6956 ft. Eleven samples were taken in these

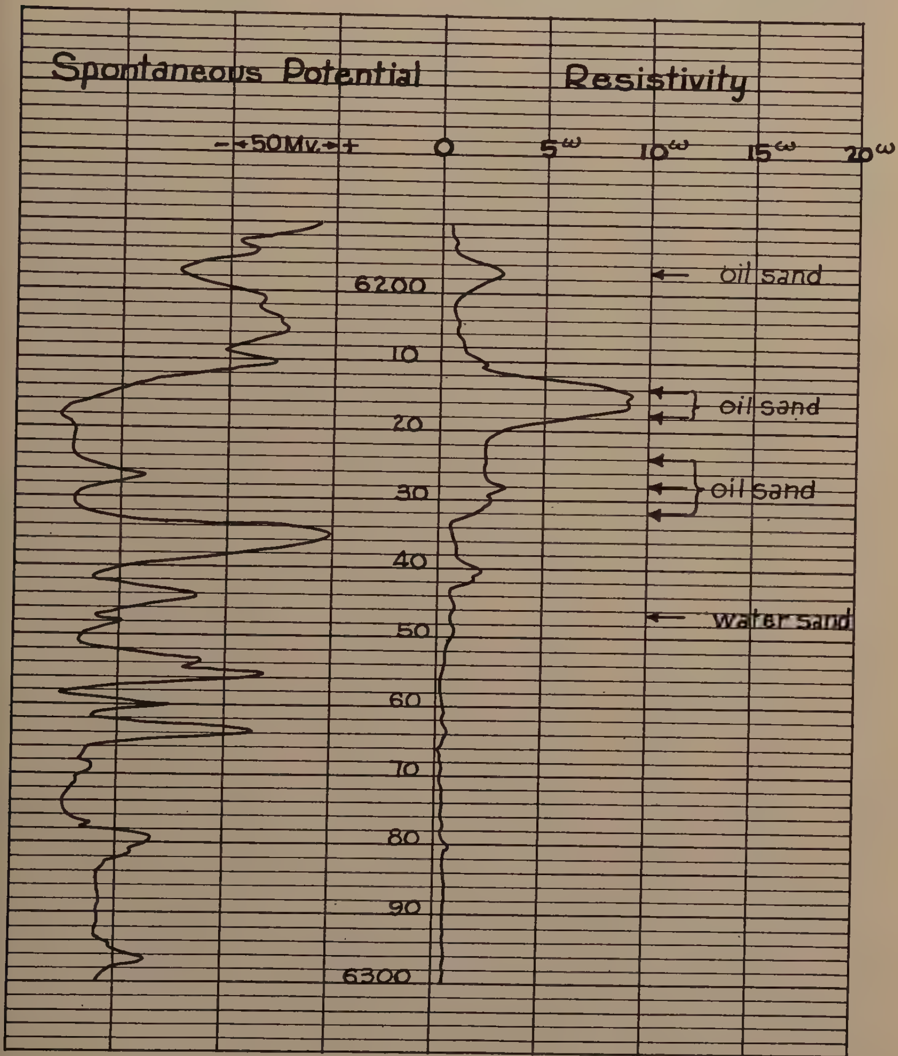


FIG. 5.—DISTINCTION BETWEEN GAS, OIL AND WATER.

sands, and outside of the valuable information concerning the texture and composition of the rocks, the presence of oil was shown in the sand at 6704 ft. while water was found in the sand at 6948 ft. Probably the low resistivity is due to considerable colloidal material, as will be explained later, but in this instance the core was not available to us for analysis.

Very often, the electrical resistivity does not undergo a sufficient variation of magnitude to permit the location of the gas-oil contact.

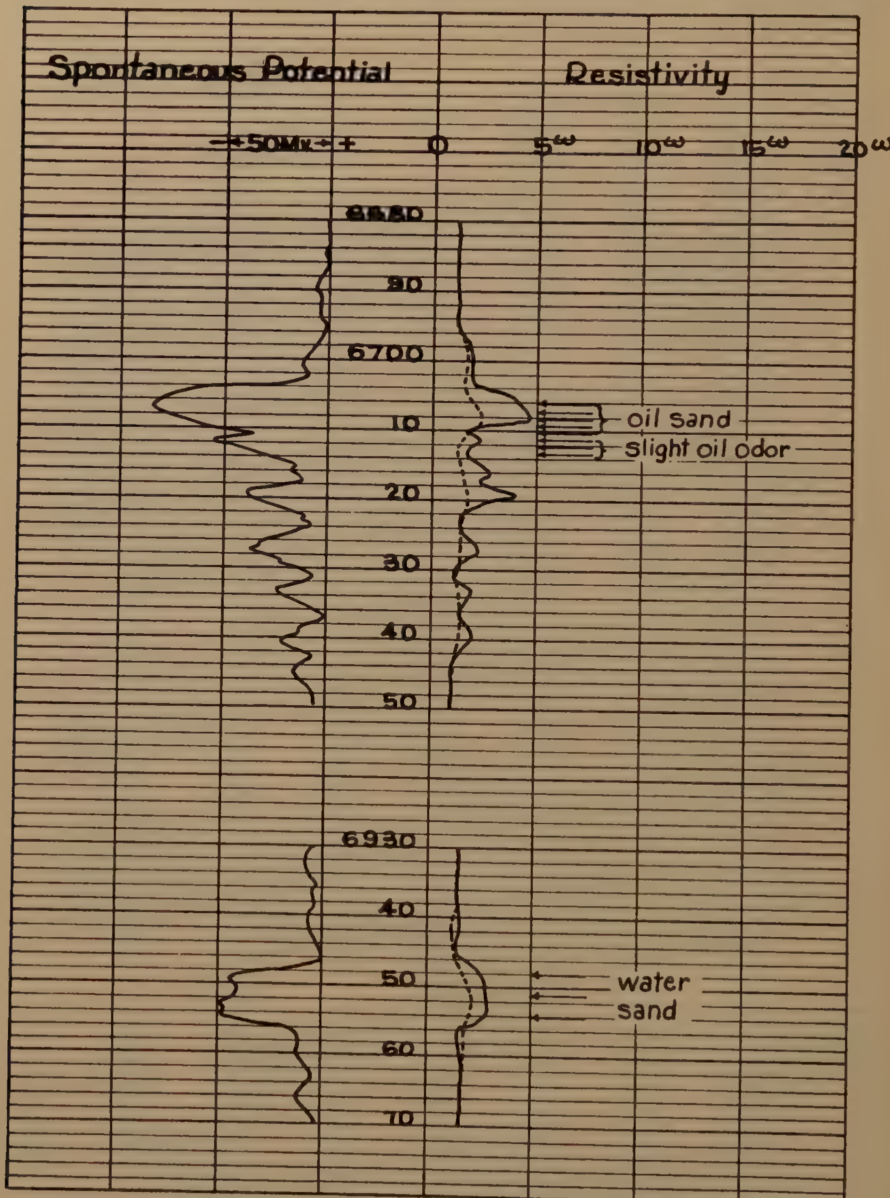


Fig. 6.—Distinction between oil and water.

Fig. 7 is a typical example of this difficulty. Three cores were taken at the break indicated on the porosity curve at 4903 ft. The content of the cores definitely proved this point to be the gas-oil contact. In addi-

tion, the low resistive sand at 4930 ft. was investigated by another shot, which demonstrated that the fluid was oil. Such a conclusion would have been impossible to reach, with certainty, without a sampling operation.

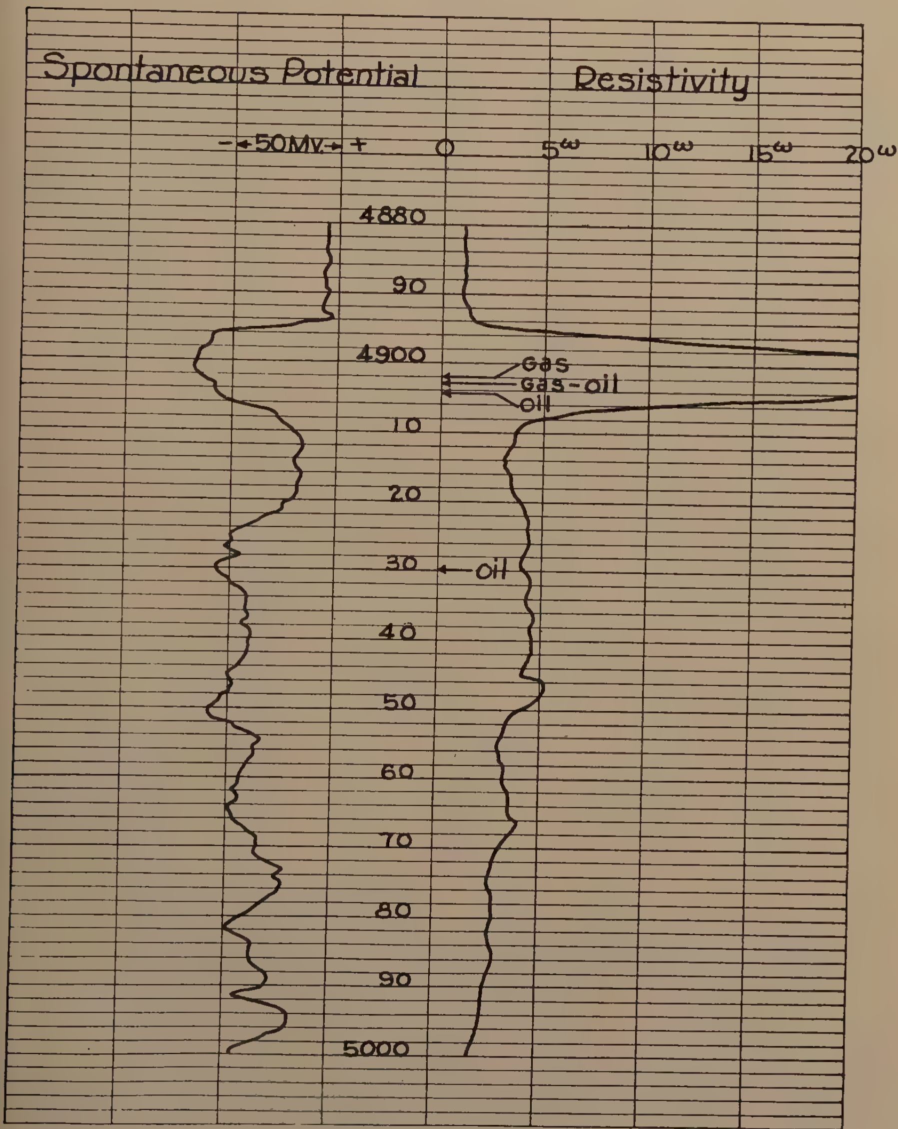


FIG. 7.—DETERMINATION OF GAS-OIL CONTACT.

In general, the oil-water contact is clearly determined by the electrical log. Cases arise, however, when two resistivity breaks are present, either of which may be the contact between oil and water. In Fig. 8, the decrease in resistivity at 4084 ft. or the break at 4092 ft. may be the

indication of water. Side-wall cores through this zone proved that water was present below 4085 ft. and oil above that point.

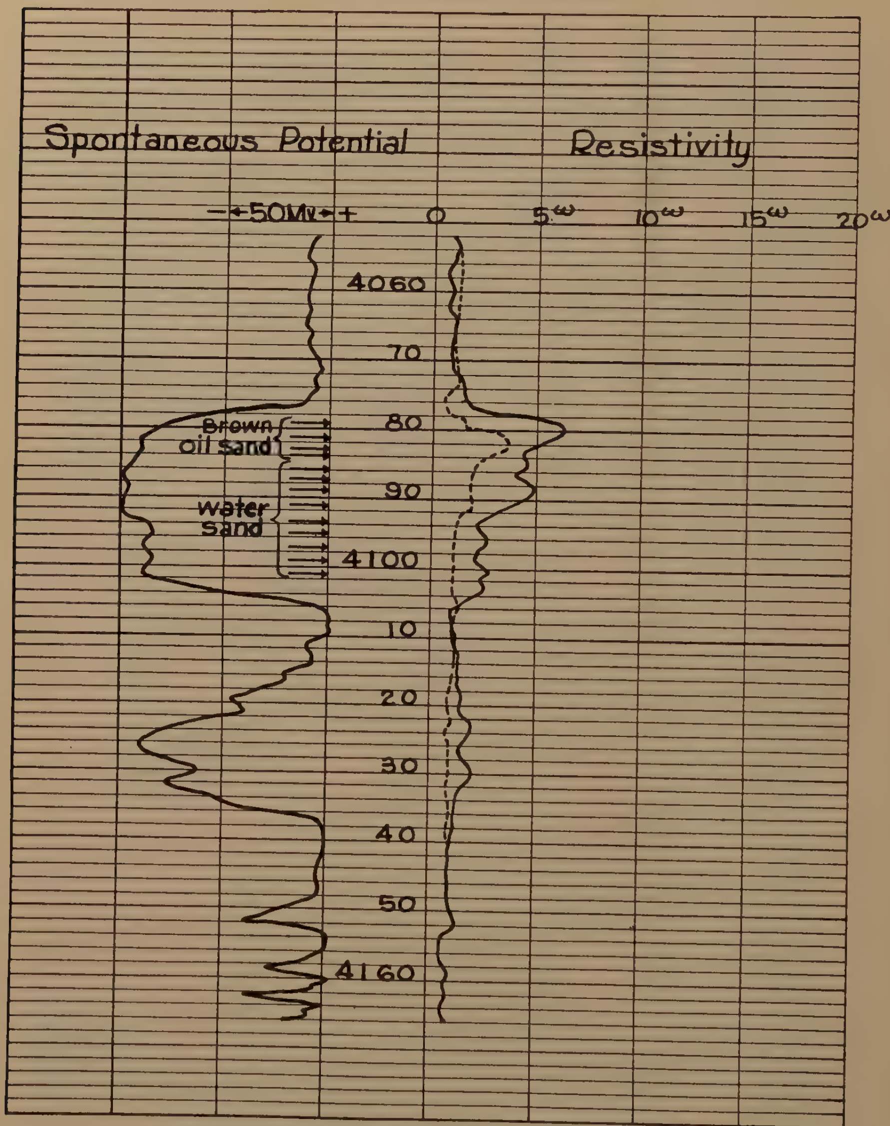


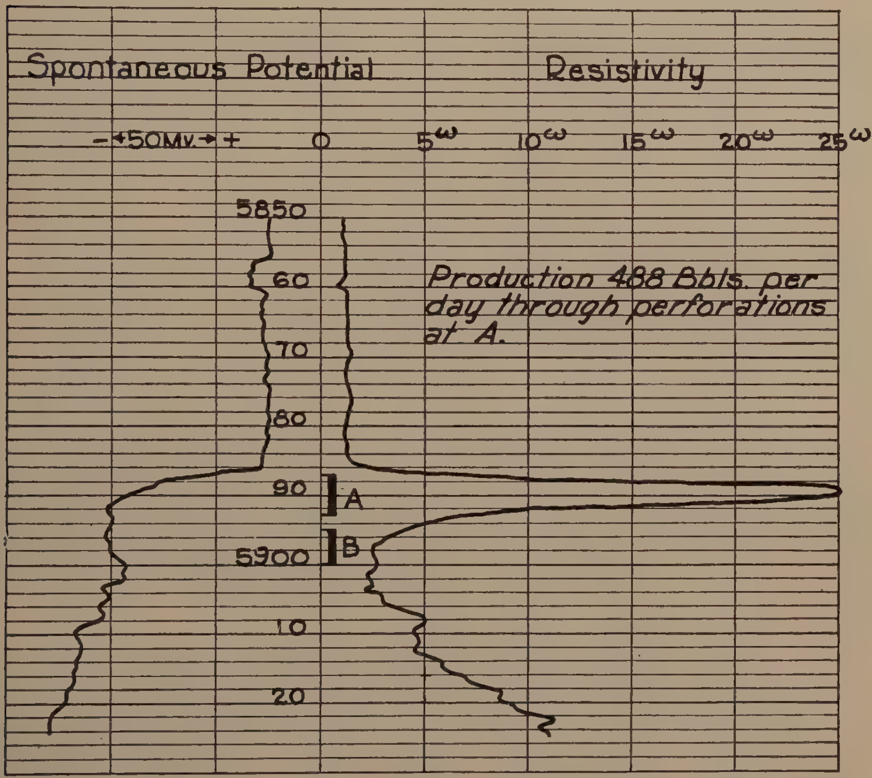
FIG. 8.—DETERMINATION OF OIL-WATER CONTACT.

CORE ANALYSIS IN THE LABORATORY

Removing samples and briefly examining them at the well is but one step in ascertaining more fully the significance of electrical data. Much more can be done in the laboratory, by measuring the salinity, the poros-

ity, and the permeability of the rocks, as well as their content in colloids and organic matter.

We have been conducting investigations along this line for some time; in fact, as early if not earlier than taking side-wall samples. The results gathered are gratifying and demonstrate that much knowledge of the

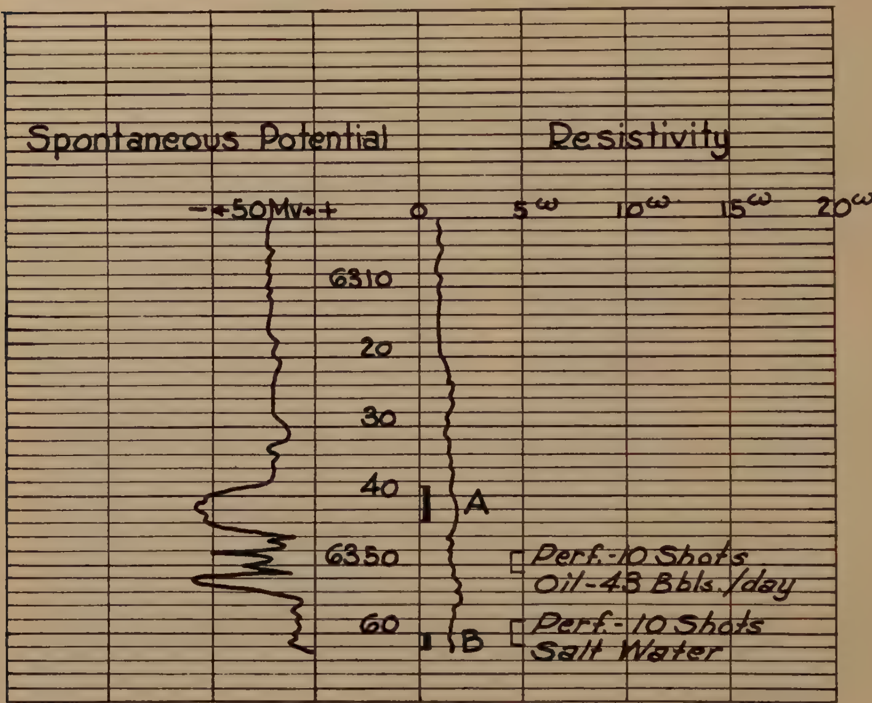


	Porosity %	Perm.⊥ md.	Perm.= md.	Silt %	Colloids %	Salinity P/mil.	Oil Sat. %
A	28.5	6630	4780	0.36	1.54	600	25.7
B	25.7	262	210	2.47	14.71	3000	12.5

FIG. 9.—RELATION BETWEEN RESISTIVITY AND COLLOID CONTENT OF FORMATIONS.

conditions at depth can be derived from a joint use of electrical logging and core analysis. Most of this work has been carried out on samples obtained by regular mechanical drilling, for the obvious reasons that side-wall sample taking has not been widely used in oil exploration until recently, and has not enabled extensive and systematic research work. It is obvious, however, that the findings are independent of the manner in which the sample has been secured from the well. Some typical observations are discussed in the following paragraphs.

Fig. 9 shows the electrical diagrams obtained on an oil sand in Refugio County, Texas. Samples were taken at *A* and *B* in order to ascertain



	Porosity %	Perm. ⊥ md.	Perm. = md.	Colloids %	Salinity pts./mil.
A	32.8	302	558	18	3480
B	17.2	2.3	10.1	18.5	2450

FIG. 10.—RELATION BETWEEN RESISTIVITY AND COLLOID CONTENT OF FORMATIONS.

the causes of the wide variation in resistivity in the interval 5890 to 5900 ft. Detailed analysis in the laboratory showed that the characteristics of the sands were as shown in Table 1.

TABLE 1.—*Sand in Refugio County*

Sample	Porosity, Per Cent	Permeability, Md.		Silt, Per Cent	Colloids, Per Cent	Salinity, Parts per Million	Oil Saturation, Per Cent
		Perpendicular to Bedding	Parallel to Bedding				
A	28.5	6630	4780	0.36	1.54	600	25.7
B	25.7	262	210	2.47	14.71	3000	12.5

The porosities being more or less comparable, the resistivities should be in the inverse ratios of the salinities, namely 5 to 1, while this ratio is actually 10 to 1. This discrepancy can readily be ascribed, for the greater part, to the influence of the colloid content.

Fig. 10 represents the diagram obtained in a well in Brazoria County, Texas. Since the sands carry oil at *A* and water at *B*, the low resistivity observed in both may appear puzzling. However, an analysis of the samples immediately furnishes some elucidation on this question, as shown by Table 2. The low resistivity at *A* is due to the high salinity and high colloid content of the formations.

TABLE 2.—*Sand in Brazoria County*

Sample	Porosity, Per Cent	Permeability, Md.		Colloids, Per Cent	Salinity, Parts per Million
		Parallel to Bedding	Perpendicular to Bedding		
A	32.8	558	302	18	9480
B	17.2	10.1	2.3	18.5	2450

Many similar examples could easily be given, but this is hardly necessary to illustrate further the trend of research, which purports to determine the causes and circumstances that will govern the variations of the porosity and resistivity data.

Conclusion

Summing up, a practical and proved method has been developed for obtaining cores from the walls of a drill hole. The side-wall samples are truly as representative as the rotary cores, and are suitable not only for supplementing the rotary core record but also for providing the entire core record. The method is much less expensive than the rotary method, both in time and money. The side-wall sample taker, used in conjunction with the electrical log, provides a practical means of securing geological information from a well. The use of this tool in oil exploration and exploitation is only beginning to find its logical and practical place in connection with electrical logging. It is our belief that it supplements the latter technique to such an extent that the two will be used jointly in the majority of cases.

Acknowledgments

We wish to acknowledge the kind cooperation of the Stanolind Oil and Gas Co., the Pan-American Production Co., Houston Production Co., Quintana Petroleum Co., Gulf Oil Corporation, and Mr. Jack Frazier, through whose courtesy it has been possible to illustrate this paper with examples of actual field work.

DISCUSSION

(W. H. Geis presiding)

L. W. Blau,* Houston, Tex. (written discussion).—This paper is exceedingly interesting. Because electrical well logs often fail to give definite information about the fluid contents of formations, it has been necessary to test many sands that appeared attractive from the electrical logs but which produced water and, likewise, it is quite possible that potential producing sands have been passed by, because, owing perhaps to connate water, the conductivity was high on the electric log. Side-wall samples from sands may be examined for the presence of oil and also for fossils. Moreover, it has been reported that measurements of the porosity and permeability have been made. There is no doubt that side-wall cores furnish pertinent and interesting information to the production geologist and engineer.

M. Muskat,† Pittsburgh, Pa.—Are the bullets obtained by the method described large enough to make permeability measurements perpendicular to the bedding plane?

R. A. Cattell,‡ Washington, D. C. (written discussion).—Does the metal disk behind the bullet act as a shear plate or merely as a separator, or "wad?" I assume that as the velocity required to penetrate the formation in the wall of the open hole is much less than that required to perforate casing, there would be little need for a shear-plate to build up high pressure in the firing chamber before the bullet starts to move.

Is there an arrangement for pulling the wires in a horizontal direction to retract the bullet? From the illustrations it seems that the pull on the wires is vertical. However, as the diameter of the section of the bullet just behind its nose is considerably larger than the diameter of the tail of the bullet, vertical tension on the wires would pull the bullet into an inclined position, and the horizontal component of the pull on the bullet would be fairly large.

T. A. Pollard,§ San Francisco, Calif.—Could this device be adapted to obtaining data on the apparently greater permeability of water-flooded portions of an oil sand to cement slurries than the permeability of oil-producing portions of the same sand to the same cement slurries. In other words, if water-producing portions of sands "take" cement more readily than oil-producing portions, sample bullets should reveal why.

E. G. Leonardon and D. C. McCann (written discussion).—The cores obtained by the side-wall sample taker are large enough for permeability measurements parallel to the bedding plane. On the other hand, special apparatus would probably be necessary to measure permeability perpendicular to this plane.

The metal disk behind the bullet does not act as a shear plate. It serves only as a piston by means of which the force of the exploding powder is applied to the bullet. The mud pressure on the large diameter of the bullet creates enough back pressure to build up a high pressure in the firing chamber.

There is no arrangement for pulling the bullet-extraction wires in a horizontal direction. Nevertheless, the low percentage of lost bullets and the condition of returned bullets and wires indicates that very little tumbling takes place during extraction from the formation. In general, the bullet axis remains parallel to the axis of the hole made when the bullet entered the formation.

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* Geophysics and Production Research, Humble Oil and Refining Co.

† Gulf Research and Development Co.

‡ U. S. Bureau of Mines.

§ Petroleum Engineer.

The side-wall sample taker cores can be used for any investigation that involves a study of samples of a formation. We have no knowledge of the side-wall cores being used for a study of permeability of sands to cement, but feel sure that it could be done.

The question of flow of various liquids through sands has been discussed at considerable length in the following papers:

Flow of Gas-liquid Mixtures through Unconsolidated Sands, by R. D. Wyckoff and H. G. Botset. *Physics* (September, 1936).

Flow of Heterogeneous Fluids Through Porous Media, by Morris Muskat and Milan W. Meres. *Physics* (September, 1936).

Flow of Oil-water Mixtures through Unconsolidated Sands, by M. C. Leverett. See page 149, this volume.

Effect of Acid Treatment upon Ultimate Recovery of Oil from Some Limestone Fields of Kansas

By R. E. Heithecker,* Member A.I.M.E.

(San Antonio Meeting, October, 1938)

Abstract†

Almost every oil well drilled into limestone formations in Kansas is treated with hydrochloric (muriatic) acid upon completion: to increase potential capacity of well and thereby increase its "daily allowable" production; to shorten time required to produce recoverable oil; and to increase quantity of oil recovered ultimately from reservoir.

Acid treating marked a forward step in the producing fields of Kansas; in fact, many old limestone fields that almost had reached their economic producing limit were "rejuvenated" with acid and their capacities to produce increased several times. It also caused a marked increase in the ultimate oil recovery of some old and nearly depleted fields of Kansas. The effect of the acid was due to the cleaning-out action by the acid at the face of the limestone, the enlargement of the small drainage channels, and the apparent penetration of the acid to previously undrained porous and saturated strata. Studies of the effects of acid were made in the Fairport field, three groups of wells in the El Dorado field and the Shutts field. Estimation of increased recoveries resulting from acid in these fields and groups of wells ranged from 1000 to 2400 bbl. per acre.

Limestone structures that had been tested by drilling and found noncommercial were later completed as commerical oil-producing formations through the use of acid. The Kansas City formation, Valley Center field of Kansas, is an example. Increased oil production and revenue from the old fields justified the reconditioning of equipment, which in most cases had become in poor mechanical condition.

The first treatment with hydrochloric acid of an oil well in Kansas was in October 1932, and by the end of 1937 almost 6000 wells had been treated. Many wells were treated more than once and the total number of treatments exceeded 8000 by the end of 1937. Approximately 12¾ million gallons of acid was required for these treatments.

The report includes 15 illustrations and 16 tables.

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* Petroleum Engineer, U. S. Bureau of Mines, Bartlesville, Okla.

† Paper published by U. S. Department of Interior, Bureau of Mines, as *Report of Investigations* No. 3445 (1939).

Decline-curve Analysis

By Henry Emmett Gross,* Member A.I.M.E.

(San Antonio Meeting, October, 1938)

Abstract†

Two types of decline curves are considered and their applications are discussed. The first is the well-known semilogarithmic decline curve having the rate of production plotted on the logarithmic scale and the time on the horizontal scale. The other curve is the percentage of oil in the fluid versus cumulative production, and it is plotted on Cartesian coordinate paper. These curves are illustrated by carefully and adequately labeled graphs. Where conditions permit application of both types of curves for rationally determining the reserves of a well, both should be applied and the most conservative reserve should be chosen.

Formulas are given for determining the economic limits. For a semilogarithmic decline curve the formula is:

$$A = B \times C \times D \times E \times F \text{ or } B = \frac{A}{C \times D \times E \times F}$$

A = total monthly operating cost (average of past year),
B = economic limit in barrels of oil per day,
C = days in an average month = 30.4,
D = market price of crude per barrel,
E = 1-royalty,
F = 1-gross production tax,
G = water production in barrels per day at the economic limit,
H = per cent oil in fluid at economic limit.

The economic limit for a per cent oil in the fluid curve is:

$$H = \frac{B}{B + G} \times 100$$

The semilogarithmic decline curve is treated first. Straight-line extrapolations on semilogarithmic paper follow the compound interest compound discount law, hence the ensuing formulas derived from this law may be used in computing reserves for such extrapolations:

$$s = \frac{\left[\frac{1}{(1+y)}\right]\left[a - \frac{a}{(1+y)^n}\right]}{\left[1 - \frac{1}{(1+y)}\right]}$$

* Associate Professor of Petroleum Engineering, Agricultural and Mechanical College of Texas, College Station, Texas.

† Paper published in *Oil and Gas Journal* (Sept. 15, 1938) **37**, No. 18, 55.

$$s = \frac{a - l}{y}$$

$$s = \frac{l - a}{1 - \log^{-1}\left[\dfrac{\log (a/l)}{n}\right]} = \frac{l - a}{1 - (a/l)^{1/n}}$$

and the number of months of future life may be found by:

$$n = \frac{\log a - \log l}{\log (s + a - l) - \log s} = \frac{\log (a/l)}{\log (1 + y)}$$

in which:

a = bbl. per month at present,
l = bbl. per month at economic limit,
y = per cent decline per month expressed as a decimal,
n = number of months future life,
s = future production or reserves.

These formulas were developed to speed up the determination of reserves and they also may be used to check detailed graphical analysis. Actual problems are worked to show how the formulas are used. Emphasis should be placed on precaution. Where logarithms are required, no less than six-place tables must be used precisely. If it is necessary to determine the reserves of numerous wells by semilogarithmic analysis, a special chart may be drawn with india ink on cellophane to speed the work. The method is shown in the paper. The manner of working semilogarithmic problems by calculus is shown, but since it is too cumbersome, the simpler algebraic methods are advised.

The second type of decline curve treated is the percentage of oil in the fluid versus cumulative production. This method can be used on single wells only, and obviously a well must be making water for the method to apply. It worked very well on the Paleozoic wells of the Mid-Continent, and particularly on the Siliceous Lime in Kansas.

"Setups" are given for the profitability analysis of individual wells.

Chapter II. Engineering Research

Significance of the Critical Phenomena in Oil and Gas Production

By D. L. Katz,* Member A.I.M.E., and C. C. Singleterry†

(San Antonio Meeting, October, 1938)

The critical phenomena have been studied during the past century but our knowledge of the critical temperatures and pressures of complex hydrocarbon mixtures still is very limited. The critical temperatures and pressures of pure substances have been examined in large numbers,[20] and in great detail.[11,17] No experimental determinations of the critical phenomena have been reported on such complex hydrocarbon systems as a reservoir fluid.

The critical temperature is defined by Taylor[18] as follows: "there is some temperature for each gas above which the gas cannot be liquefied. This temperature is called the critical temperature." The critical pressure of a pure substance is the vapor pressure at the critical temperature. It should be noted that these definitions refer to a given substance in the pure state and do not mean that the pure substance cannot be liquefied in the presence of a second constituent.

The normal procedure for obtaining the critical temperature of a substance is to heat it in a glass tube [1,20] under pressure until the meniscus between the liquid and vapor phase disappears, although other methods, especially for mixtures, have been used.[13,14] However, when considering oil and gas reservoirs, it is more enlightening to consider a critical phenomenon that occurs when a mixture of oil and gas are compressed at a reservoir temperature until the meniscus disappears because the two phases become equal in composition. This conception, along with erroneous applications of the definition of the critical phenomena of a pure substance to that pure substance when it is part of a complex mixture, has caused confusion even among persons familiar with the classical theories.

The purpose of this paper is to discuss the critical phenomena of pure substances and mixtures and to report experimental data on a mixture of

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* Assistant Professor, Department of Chemical and Metallurgical Engineering, University of Michigan, Ann Arbor, Mich.

† Universal Oil Products Co., Riverside, Ill.

[20] References are at the end of the paper.

natural gasoline and natural gas to a critical pressure and on mixtures of crude oil and natural gas up to 9000 lb. per sq. in. One observation of the insolubility of tar constituents of a crude oil in the fluid phase in the region of the critical is described. The significance of this information to problems in oil and gas production is discussed.

Pure Substances

The critical conditions for 30 pure substances, including nine hydrocarbons, were determined by Young.[20] Since his work, the critical properties of most naturally occurring hydrocarbons below octane have been investigated, as given in Table 1. The vapor pressure and critical data are similar to that for ethane shown on Fig. 1.[5,22] The line *KDB* gives the pressures and temperature at which vapor and liquid will

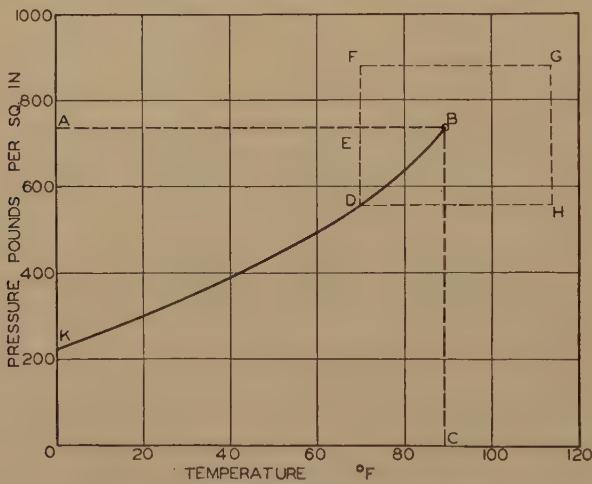

Fig. 1.—Vapor pressure of ethane.

exist in equilibrium. The area *ABK* is the compressed liquid region while the area *KBC* is the superheated vapor region. Outside of area *ABC*, the substance should be referred to as a fluid. If the liquid at *D* were compressed to *F* and referred to as a compressed liquid at these conditions, it would be possible to follow path *FGHD* and change a liquid into a vapor without a phase change. Accordingly, the substance should be considered to have passed into a uniform fluid region when going above the critical temperature or pressure; for instance, from *E* to *F*.

The critical temperature has little significance with respect to the behavior of a pure constituent in a complex mixture, although it is a good reference state for correlating data on pure compounds.[9,3] The equilibrium constants for ethane from 40° to 200° F. when the ethane is in a crude-oil system[8] show no indication of having passed through any critical temperature at 89° F. Thus critical temperature refers to a definite system, and when this system becomes a part of another system the

critical temperature of the first system has little significance for the second system.

The approach of the liquid and vapor densities towards each other in passing from K to D, and the meeting of the densities at the conditions of

TABLE 1.—*Critical Constants of Pure Hydrocarbons and Typical Mixtures*

Hydrocarbon	Critical Temperature			Critical Pressure		Critical Density	
	Deg. F.	Deg. R.	Deg. K	Lb. per Sq. In. Abs.	Atm.	Grams per C.C.	Lb. per Cu. Ft.
Methane........	−116	344	191	673	45.8	0.161	10.06
Ethane..........	90	549	305	717	48.8	0.209	13.1
Propane........	205	665	370	617	42.0	0.228	14.2
i-butane........	272	732	407.1	544	37.0	0.234	14.6
n-butane........	306	766	426	545	37.1	0.232	14.5
i-pentane.......	369	829	461	483	32.9	0.235	14.7
n-pentane.......	386	846	470.3	485	33.0	0.232	14.5
n-hexane........	454	914	508	435	29.6	0.234	14.6
n-heptane.......	512	972	540	397	27.0	0.234	14.6
n-octane........	564	1,024	569	361	24.6	0.233	14.6

METHANE-PROPANE SYSTEM[14]

Composition, Mol Per Cent	Mol. Wt.	Critical Temperature		Critical Pressure		Critical Density	
		Deg. C.	Deg. F.	Lb. per Sq. In.	Atm.	Grams per C.C.	Lb. per Cu. Ft.
Methane:							
10............	41.2	91.0	196	766	52.1	0.232	14.5
20............	38.4	81.2	178	891	60.6	0.232	14.5
30............	35.6	70.9	160	1,018	693	0.232	14.5
40............	32.8	59.3	138	1,158	78.8	0.231	14.4
50............	30.0	46.3	115	1,291	87.9	0.231	14.4
60............	27.2	31.1	88	1,408	95.7	0.229	14.3

ETHANE-HEPTANE SYSTEM[10]

Ethane:							
26.5..........	81.6	242	468	682	46.4	0.260	16.2
58.7..........	59.0	190	374	1,106	75.2	0.266	16.6
77.1..........	46.1	136	277	1,263	86.0	0.279	17.4
88.7..........	38.0	88	190	1,132	77.0	0.272	17.0
96.8..........	32.3	49	120	850	57.8	0.248	15.5

GASOLINE AND NAPHTHA[1]

Gasoline........	109	266	586	542	36.9	0.325	20.2
Naphtha........	110	268	591	434	29.5	0.258	16.1

B at the critical density is the general behavior of pure substances. The rate of change in density with pressure reaches a very high value near the critical, for Young[21] reports that isopentane density is 0.195 grams per cubic centimeter at 25,000 mm. mercury pressure and is 0.257 grams per c.c. at 25,030 mm. mercury, all at a constant temperature of 0.05° C. above the critical temperature. This fact makes it possible to enclose a given quantity of a substance in a tube and measure a meniscus disappearance at a temperature close to the critical, even though the quantity of substance in the tube does not give the critical density at the critical temperature. If less substance than that required to give the critical density is enclosed, the liquid-vapor meniscus should go to the bottom of the tube, but really it disappears, with a slight temperature rise due to the rapid change in properties at the critical. Similarly, too much substance would completely liquefy, but again a slight increase in temperature to the critical would cause the meniscus to disappear.

Maass and co-workers[17,19] have carried on studies with closed tubes and more recently with variable-volume apparatus,[11] in which they show that liquid molecules tend to have some of their cohesive forces acting for 2° to 5° C. above the critical temperature. The use of closed tubes made their early work inconclusive but the recent report shows the same phenomena at the true critical volume. The small range over which the discontinuity exists makes the information of interest only from the classical viewpoint.

Mixtures of Hydrocarbons

Critical data along with phase diagrams have been reported for several simple mixtures of pure hydrocarbons[4,10,14,15] with critical constants as given in Table 1. The critical temperature of mixtures follows the law of additive properties on a weight or liquid-volume percentage basis reasonably well but the critical pressures rise appreciably above the critical pressure for either constituent.

The phase diagram of one mixture of the methane-propane system is shown in Fig. 2. The boundary curve was copied directly from Sage, Schaafsma and Lacey[14] but the percentage-liquid lines were computed from Sage, Schaafsma and Lacey's vapor-liquid equilibria data. This diagram will be used to illustrate qualitatively the behavior of complex mixtures, even though the shape of the phase diagram for complex mixtures may be of considerably different proportions, especially in the direction of an enlarged pressure quantity between the boundary curves.

The line ELA is the vapor pressure or bubble-point line, the density of the liquid decreasing from E to A. The line $FOHBA$ is the dew point or complete vaporization line, with a reciprocal increase in density of the saturated vapor to point A, the critical point. Liquid exists above the critical temperature of the system. This liquid is richer in propane than

the average for the system and if removed from the vapor phase and examined for its phase relations, would be found to be below its critical temperature at the conditions existing in the 40 per cent methane, 60 per cent propane system. The critical temperature of a mixture refers to the mixture passing from the liquid state to the region of uniform fluid with a slight temperature rise, and the critical temperature must be the maximum temperature at which a bubble point will exist for the mixture.

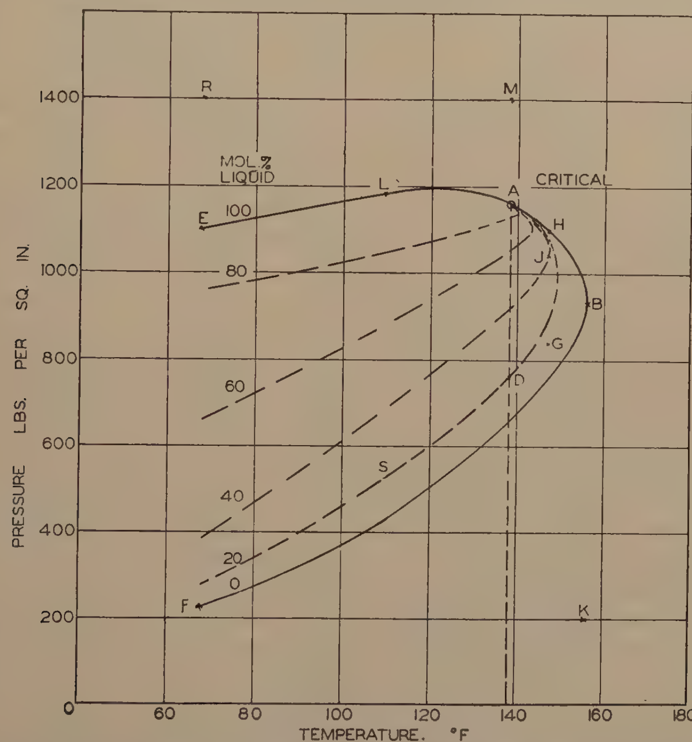

FIG. 2.—PHASE DIAGRAM OF ONE MIXTURE OF THE METHANE-PROPANE SYSTEM. 40 mol per cent methane, 60 per cent propane. After Sage, Schaafsma and Lacey.[14]

The critical pressure is the vapor or bubble-point pressure at the critical temperature.

The reverse in the dew-point and percentage liquid lines above the critical temperature permits the phenomena of retrograde condensation. If the pressure and temperature on a mixture corresponds to H, it is a saturated vapor. Dropping the pressure isothermally will bring the mixture to point J, or 40 mol per cent liquid, and subsequent pressure drops will pass continuously through 20 to 0 per cent liquid. This is the process by which reservoir vapors will produce liquid when the pressure is dropped before passing through a vapor-liquid separator. A similar retrograde phenomenon will occur above the critical pressure of

the mixture. By increasing the temperature on liquid L, normal vaporization will occur, but the vapor will again condense to reach the complete liquid state. These two phenomena are observed only for temperatures or pressures above the critical values for the system considered.

The decrease of the liquid density to the critical by temperature increase along line ELA may be duplicated by increasing the pressure isothermally at the critical temperature.[14] Thus if a 20 mol per cent liquid, 80 mol per cent vapor mixture at D were compressed it would liquefy completely but pass to the region of uniform fluid just as liquefaction was completed. If an unknown vapor-liquid mixture were compressed isothermally in an attempt to meaure the critical pressure at the chosen critical temperature, it would liquefy, vaporize, or reach a critical pressure, depending on whether the volatile constituents were deficient, in excess, or the exact quantity for the mixture to have its critical temperature at the chosen temperature. In cases of liquefaction or vaporization to a uniform phase, the density and composition of liquid and vapor phases would not become the same as the uniform phase was approached and the relation of the mixture to the critical temperature could be ascertained by following the compositions of the two phases during compression. However, if the densities of the two phases were relatively close as a uniform phase occurred, this pressure would approach the critical pressure just as the temperatures for meniscus disappearance in sealed tubes approached the critical temperature.

This isothermal decrease of liquid density to a critical pressure has been shown to be an important criterion for correlating equilibrium constants.[7] The equilibrium constants plotted as a function of pressures on isothermal plots converge to unity at this critical pressure. As stated above, considerable freedom in systems may be expected with small changes in critical pressure at a given temperature.

The constant temperature of reservoirs makes investigations on liquid and gas mixtures at reservoir temperatures more convenient than the method of changing temperatures. If a critical temperature is not observed with a given ratio of liquid to vapor, the volatility of the mixture can be changed with results such as have been found for the methane-propane system.[14] The difficulty of finding an exact composition for a chosen critical should be of the same nature as filling sealed tubes to measure critical temperatures, hence a reasonable degree of freedom may be expected without serious error in the critical pressure.

Experimental Determinations at High Pressure

An apparatus of the type used by Katz and Hachmuth[8] was modified to give one more sample line from the equilibrium bomb and constructed to withstand pressures above 10,000 lb. (Fig. 3). The bomb had a volume of 700 c.c. which was decreased to about 575 c.c. when the motor was inserted.

The experiments planned were to place crude oils in the bomb and pump in natural gas until pressures were reached that gave vapors having a considerable content of heavy hydrocarbons. Then the pressure could be increased by injecting mercury into the bottom of the bomb.

The method chosen to determine in a simple and quick manner the degree to which the vapor-phase composition had approached the liquid

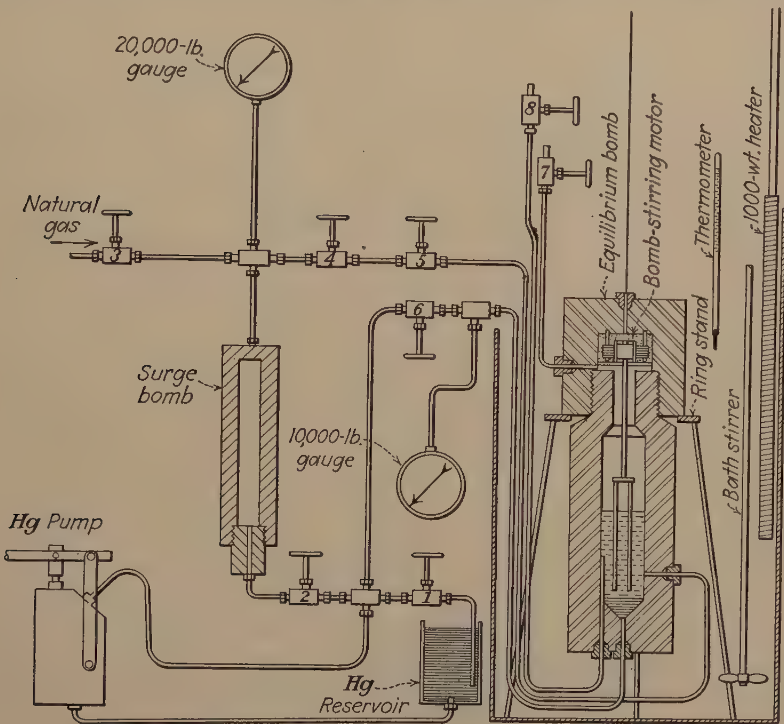

FIG. 3.—ARRANGEMENT OF APPARATUS.

composition was to pass the bomb fluid through a graduated glass trap at dry-ice temperature and atmospheric pressure. The gas density was measured and its quantity obtained by water displacement. The volume of liquid collected was reported for crude-oil mixtures and weighted quantities for the mixtures of natural gasoline and gas. This method was known to be qualitative and was intended to explore the mixtures to permit fractional analyses of vapors and liquids just below or at critical conditions.

A 34° A.P.I. stock-tank crude oil similar to the one for which the analysis is given in Table 4, and a casinghead gas sample (0.69 gravity) at 1100 lb. were obtained from an Arkansas field. Approximately 200 c.c. of crude was placed in the equilibrium bomb and the high-pressure gas injected, first at the cylinder pressure and then compressing the gas above the cylinder pressure in bomb *D*. At a pressure of 6000 lb.

the contents of the bomb were stirred and samples of liquid and vapor were withdrawn to ascertain the relative quantity of heavy hydrocarbons in the two phases.

At the 6000-lb. pressure no measurable liquid was collected when the vapors were passed through the trap, and so the pressure was raised by gas injection to 9300 lb. at 80° F. At this condition, the yields of liquid recovered from the vapor are reported in Table 2. The liquid phase also was passed through the trap but froze at dry-ice temperatures and so was separated at room temperature. This experiment

TABLE 2.—*Trap Yields on Saturated Vapors and Liquids*

System	Pressure, Lb. per Sq. In.	Temperature, Deg. F.	Phase	Volume Liquid,[a] C.C.	Weight Liquid,[b] Grams	Volume Gas Collected, C.C. at 80° F.[c]	Grams Liquid, per Liter Gas	Cu. Ft. at 60° F.; 14.7 Lb. per Bbl. Liquid	Sp. Gr. Gas
Arkansas crude	9,300	80	Upper	0.20	0.15	2,305	0.065	58,700	
and natural gas.		80	Lower	6.5	5.52	1,285	4.29	1,010	
175 Arkansas	8,900	70	Upper	0.30	0.225	1,251	0.180	21,200	0.76
crude, 50 natural			Lower	4.2	3.57	945	3.78	1,140	0.87
gasoline and			Upper	0.29	0.217	1,130	0.192	19,900	0.76
natural gas.	8,900	120	Upper	0.25	0.187	962	0.194	19,600	0.78
			Lower	3.8	3.32	945	3.51	1,270	0.87
	8,900	198	Upper	0.45	0.337	988	0.34	11,150	0.81
			Lower	2.3	1.95	663	2.86	1,470	0.83
	8,900	200	Upper	0.38	0.285	882	0.323	11,800	0.80
			Lower	3.0	2.55	784	3.23	1,330	0.82
	8,900	280	Upper	0.45	0.337	1,142	0.295	13,000	0.79
			Lower	3.8	3.23	866	3.73	1,160	0.82
	6,000	200	Upper	0.10	0.075	823	0.09	41,900	0.71
			Lower	3.5	2.97	683	4.35	995	0.84
Natural gasoline	3,000	80	Upper	0.28	0.190	803	0.237	14,600	0.682
and natural gas.		80	Lower	1.35	0.920	785	1.171	2,960	0.703
	3,180	80	Upper	0.42	0.284	803	0.354	9,680	0.686
		80	Lower	1.45	0.982	858	1.145	3,010	0.711
	3,790	80	Upper	1.15	0.784	885	0.865	3,920	0.690
		80	Lower	1.63	1.106	960	1.151	3,000	0.682
	4,090	79	Upper	1.56	1.059	878	1.207	2,860	0.678
		79	Lower	1.51	1.027	862	1.19	2,900	0.693
	4,600	80	Upper	2.10	1.425	1,175	1.21	2,840	

[a] Measured for crude-oil systems.
[b] Measured for natural gasoline-gas system only.
[c] Total pressure 740 mm.; partial-pressure hydrocarbons, 715 mm.

showed that considerably higher pressures would be required to reach a critical pressure for the mixture chosen.

Accordingly, a mixture of 175 c.c. of the crude and 50 c.c. of an Oklahoma City natural gasoline* were charged to the bomb and gas was injected as before. This mixture was raised to 8900 lb. and the phases

* 14.3 lb., Reid v.p. at 100° F., 81° A.P.I. Composition from distillation[2] 10.2 per cent butane, 39.6 per cent pentane, 25.1 per cent hexanes, and 25.1 per cent heptanes plus, on volume basis. Surface tension 17.2 dynes at 26° C.

examined at four temperatures to give the data on Table 2. The concluding run of the series was at 6000 lb. to show the effect of lower pressure.

The data so accumulated were not in the neighborhood of a critical pressure, therefore a more volatile sample, the natural gasoline, was chosen as the liquid phase, with the hope that the critical conditions would come below 10,000 lb. A charge of 205 c.c. of gasoline was followed by the natural gas to a pressure of 3000 lb. at 80° F. The failure of the stirrer to give equilibrium in the crude-oil experiments was considered a possible explanation of the high critical pressures indicated for the crude oils, therefore the bomb was rocked manually to insure equilibrium.

The upper-phase and lower-phase fluids were passed through the trap immersed in dry ice, with the results shown in Table 2. Because of the relatively high concentration of heavier constituents in the upper phase, no more gas was injected and the pressure was raised above 3000 lb. by mercury injection. Samples were taken at constant temperature and pressures shown with the upper and lower phases giving similar liquid-gas ratios at 4090 lb. At 4600 lb. the upper phase showed no change from the 4090 lb. The consideration of the positions on the phase diagram traversed will follow a description of an experiment on the solvent action of this uniform, highly volatile phase.

The absence of tarry constituents in fluids containing high concentrations of volatile constituents is to be expected from solvent deasphaltizing operations and the work of Pilot.[12] To check this surmise, 25 c.c. of a 26.2° A.P.I. Kansas crude having an analysis similar to that given in Table 5 was injected at 5000 lb. per sq. in. and 80° F. into the estimated 400 c.c. of fluid remaining from the experiments described above. The contents of the bomb containing mercury were agitated and samples of the upper phase withdrawn through the dry-ice trap showed a straw colored liquid with no trace of the tar dissolving in the volatile fluid. The entire contents of the bomb maintained at 5000 lb. was then taken through the trap at atmospheric pressure and temperature, with a yield of light amber liquid of 0.747 sp. gr. at 60° F. The mercury layer, including some emulsion, followed the clear liquid, showing the tar phase to be small. The emulsion was centrifuged to yield about 6 c.c. of a tar almost solid at 80° F.

Correlation of Data

The data on the natural gasoline-natural gas system give a smooth curve for the liquid yield in the trap as a function of pressure (Fig. 4). Immediately one wonders if the mixture became a liquid, a vapor, or a critical fluid at the junction of the vapor and liquid curves. It seems unlikely that one would choose the correct mixture whose critical temperature was 80° F. As the uniform-phase yield was similar to the liquid-phase yield, it follows that the possibility of the complete lique-

faction is greater than that of complete vaporization. When remembering the rapid changes in vapor and liquid ratios and densities in the neighborhood of the critical temperature and pressures for pure compounds the approach to the critical pressure and temperature for this system may be rather close even though liquefaction or vaporization did occur. Accordingly, the critical pressure of a mixture of which

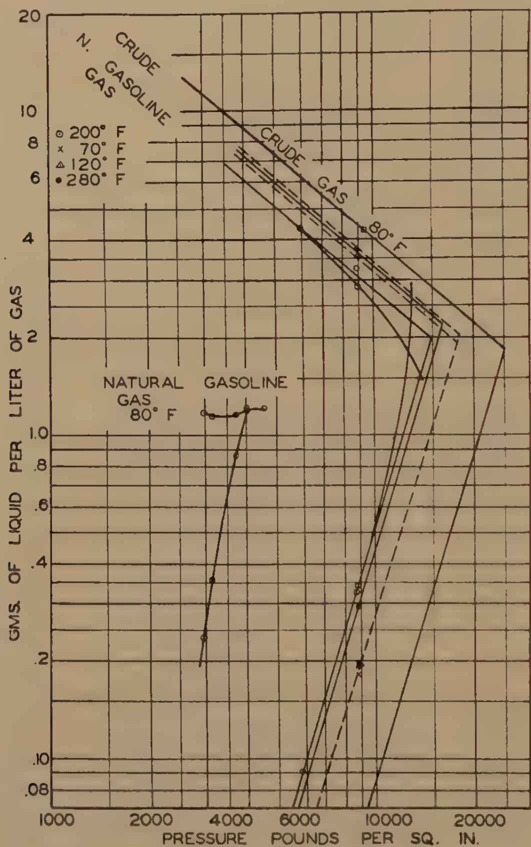

FIG. 4.—TRAP YIELDS FOR VAPORS AND LIQUIDS.

the critical temperature is 80° F. must be well within 200 lb. of the 4090 lb. measured.

The consistency of the data on the natural gasoline-natural gas system gave some hope of interpreting the former data on the crude-oil mixtures. Because of the difference in measurement of liquid collected, it was necessary to convert the volumetric trap yields into weight yields, using estimated densities of 0.75 and 0.85 grams per c.c. for the vapor and liquid trap samples respectively. These conversions (Table 2) permitted the plotting of the points as shown on Fig. 4. Guided by the two

pressures measured at 200° F. and the shape of the curves for the mixture of natural gasoline and gas, curves have been inserted that should give a rough indication of the critical pressures of the mixtures studied. The more volatile natural gasoline-crude oil blend shows critical pressures of the order of 15,000 to 18,000 lb. with only a small decrease indicated for rise in temperature from 70° to 200° F. The less volatile mixture of

TABLE 3.—*Computed Compositions of Critical Mixtures*

OKLAHOMA CITY CRUDE[8]

Gas	Mixture at 4500 Lb., 40° F.		Mixture at 5000 Lb., 200° F.	
	Mol Fraction	Wt. Fraction	Mol Fraction	Wt. Fraction
Methane	0.6620	0.1940	0.6800	0.2228
Ethane	0.0650	0.0358	0.0670	0.0412
Propane	0.0440	0.0355	0.0505	0.0455
Butanes	0.0320	0.0342	0.0333	0.0396
Pentanes	0.0225	0.0298	0.0215	0.0317
Hexanes	0.0195	0.0309	0.0215	0.0379
Crude residue	0.1550	0.6398	0.1262	0.5813
Molecular weight	54.4		48.9	

ESTIMATED MIXTURE OF NATURAL GASOLINE AND NATURAL GAS

	Critical Conditions about 4090 Lb. per Sq. In. and 80° F.	
	Mol Fraction	Wt. Fraction
Nitrogen	0.037	0.026
Carbon dioxide	0.007	0.007
Methane	0.538	0.216
Ethane	0.062	0.046
Propane	0.024	0.026
Butanes	0.050	0.073
Pentanes	0.138	0.250
Hexanes	0.076	0.162
Heptanes	0.068	0.194

crude oil and natural gas indicates a critical pressure of the order of 25,000 pounds.

These high critical pressures are in apparent conflict with the indicated critical pressures of 4500 and 5000 lb. per sq. in. for the mixtures of Oklahoma City crude oil and gas at 40° and 200° F.[8] However, the composition of the uniform fluid phase, especially with reference to the intermediate constituents ethane, propane, butane, etc., may have a marked effect on the critical pressure. The desirable data would be a fractional anal-

ysis of the high-pressure fluids in question, and although these analyses were planned in the critical studies, an attempted fractionation of the uniform fluid of the natural gasoline-gas system failed because of inadequate vacuum in the column. The density of the liquid measured at 0.68 grams per c.c., gas density, and gas-liquid ratio give a computed molecular weight of 39.2 for the fluid. This value, the composition of the natural gasoline, and the composition of a gas similar to that used,

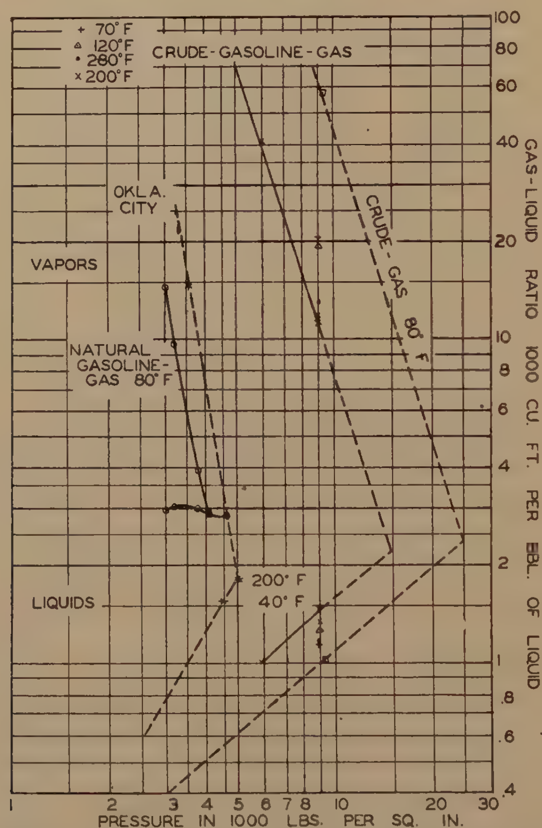

FIG. 5.—GAS-LIQUID RATIOS WHEN SEPARATING HIGH-PRESSURE VAPORS AND LIQUIDS AT CONDITIONS EQUIVALENT TO 80° F. AND 370 POUNDS.

give an approximate composition for the uniform phase as shown in Table 3.

A correlation of critical pressures of mixtures containing methane and less volatile constituents might be made in the direction shown by Sage and Lacey.[15] Computed properties on the samples in these experiments and of the Oklahoma City crude[8] along with binary mixture data[16,15] should not be expected to cover the field but might give a rough method of estimating critical pressures.

Application of Information to Oil and Gas Reservoirs

The use of a trap in separating heavy constituents from the effluent from a well is similar to the experiments on high-pressure vapors and liquids. The gas-oil ratios are a rather good qualitative guide as to phases expected to exist in the reservoir at a given temperature and pressure. The yields of liquid in the experiments on a basis of cubic feet of gas per barrel of liquid were computed in Table 2 and plotted on Fig. 5. The trap vaporization conditions at about minus 100° F. and one atmosphere corresponds on a vapor-pressure chart to 80° F. and 370 lb. absolute, or in the customary separator operating range. The data show that gas-liquid ratios of 3920 cu. ft. per barrel of liquid would be obtained when passing the vapors of the natural gasoline-natural gas system saturated at 3790 lb. and 80° F. through a separator at about the conditions of 80° F. and 370 pounds.

It is also shown that vapors saturated at 8900 lb. and 200° F. from the crude oil-natural gasoline-natural gas system would have ratios of the order of 11,200 cu. ft. per barrel of separator liquid. The volatility of the system has considerable effect upon the gas-liquid ratio, as shown by the ratio of 58,000 for the crude-natural gas system when saturated at 80° F. and 9300 pounds.

It is possible to estimate the critical concentrations of the constituents in the mixtures of Oklahoma City crude oil and natural gas by extrapolation of liquid and vapor concentrations to the same value at the estimated critical pressures. These analyses, shown in Table 3, and the equilibrium constants were used to compute the gas-liquid ratios expected when separating the mixture at 370 lb. and 80° F. The gas-liquid ratios of the crude saturated at 2600 lb. and 132° F., and an experimental analysis of vapors saturated at 3527 lb. and 200° F.[8] when in equilibrium at the above conditions, give an approximate gas-liquid ratio diagram for the Oklahoma City crude-gas system. These data point to a gas-liquid ratio of the order of 1500 to 4000 cu. ft. per barrel liquid for the critical fluids mentioned when separating at conditions equivalent to 80° F. and 370 lb. per sq. inch.

The ratio of gas to liquid found by Eilerts and Shellhardt[6] for a reservoir fluid at 3177 lb. and 228° F. when separated at 330 lb. and 76° F. was 34,800 cu. ft. per barrel of stock-tank liquid and a somewhat lower value when computed on basis of separator liquid. This point is in the region of ratios corresponding to saturated vapors. Although a saturated vapor might carry a small quantity of liquid phase and have a ratio corresponding to a vapor, their report does not give conclusive evidence.

The color of liquids produced from wells is sometimes used as a very rough guide as to the probable phases present in the reservoir, and the following observations of these experiments should be noted. All

vapors when subjected to a condensation process corresponding to the separation conditions described gave a liquid of water white to deep straw color. Because they were dark in color when charged to the apparatus,

Table 4.—*Analysis of Stock-tank Sample*[a] *of Arkansas Crude*

Air Distillation	Straight Run, 300 C.C. of Charge		General Crude Tests
Temperature, Deg. F.	Total Per Cent Over	Gravity, Deg. A.P.I.	Gravity, 32.6° A.P.I. at 60° F. Bottom Settlings and Water, 2 Per Cent
Up to 122	1		Sulphur, 1.71 per cent
122–167	2.7	78.7	Pour test, 10° F.
167–212	6.2		Saybolt viscosity, 75 sec. at 70° F.
212–257	10.0	65.2	Saybolt viscosity, 54.7 at 100° F.
257–302	14.4	59.2	Conradson carbon residue
302–347	19.8	53.8	Test of still residue, 9.92 per cent
347–392	24.3	49.2	Color of crude brownish black
392–437	29.1	45.3	
437–482	33.7	42.5	Initial boiling point of crude, 82° F.
482–527	39.9	39.6	

Vacuum Distillation at 40 Mm.			Viscosity at 100° F.	Cloud Test, Deg. F.
Up to 392	44.3	35.3	40	Below 30
392–437	49.3	33.3	45	30
437–482	54.9	30.1	55	50
482–527	59.5	27.5	78	65
527–572	65.1	25.4	123	90

Distillation Summary

Product	Per Cent	Gravity at 60° F.	Saybolt Viscosity at 100° F., Sec.	42 Gal. per Bbl.
Gasoline-naphtha	24.3	61.4		10.21
Kerosene	14.8	42.6		6.21
Gas-oil	10.4	35.8	Under 50	4.37
Light lubes	10.2	31.7–26.5	50–100	4.28
Medium lubes	5.4	26.5–24.2	100–200	2.27
Viscous lubes			Over 200	
Still residue	32.9			13.82
Distillation loss	2.0			0.84

Surface tension at 26° C. = 25.9 dynes per centimeter.

[a] From same pool as sample used in experiments.

the crudes gave dark liquids. The uniform fluid phase of natural gasoline-natural gas in the region of the critical conditions and in the presence of very dark crude oil gave a straw colored liquid upon separation. This

relationship of the highly volatile fluid to the injected crude oil was similar to that of a vapor to a liquid.

TABLE 5.—*Analysis of Stock-tank Sample[a] of Kansas Crude*

Air Distillation	Straight Run, 300 C.C. of Charge		General Crude Tests
Temperature, Deg. F.	Total Per Cent Over	Gravity, Deg. A.P.I.	Gravity, 24.4° A.P.I. at 60° F. Bottom Settlings and Water, 0 Per Cent
Up to 122			Sulphur, 0.76 per cent
122–167			Pour test below 5
167–212			Saybolt viscosity, 264 at 100° F.
212–257	2.13	60.5	Conradson carbon-residue test of still residue, 18.4 per cent
257–302	5.33		
302–347	8.66	50.6	Color of crude, brown and black
347–392	12.46		
392–437	16.53	44.7	Initial boiling point of crude, 212° F.
437–482	20.93	41.9	
482–527	27.66	39.4	

Vacuum Distillation at 40 Mm.			Viscosity at 100° F.	Cloud Test °F.
Up to 392	31.93	33.8	40.2	
392–437	35.50	32.1	47.5	
437–482	41.90	28.9	62.3	48
482–527	46.63	27.5	91.0	66
527–572	52.60	25.9	137.7	80

DISTILLATION SUMMARY

Product	Per Cent	Gravity at 60° F.	Saybolt Viscosity, at 100° F.	42 Gal. per Barrel
Gasoline-naphtha	12.46	54.4		5.23
Kerosene	10.54	46.2		4.43
Gas-oil	11.50	35.0	Below 50	4.83
Light lubes	10.75	27.6	50–100	4.51
Medium lubes	7.35	26.1	100–200	3.08
Viscous lubes	None			
Still residue	45.40			19.08
Distillation loss	2.00			0.84

Surface tension at 26° C. = 27.8 dynes per centimeter.

[a] From same pool as sample used in experiments.

This analysis is very crude but, along with a method of estimating critical pressures from the analyses of the mixtures, should at least give a cue as to the probable phases present in a reservoir from gas-liquid

ratio, reservoir temperature and pressure, and analysis of well effluent. If the probable phase or phases present are known, the behavior with subsequent pressure changes should be considered.

The identification of the phase relations of a well effluent when it is present at the reservoir conditions assists in choosing production methods and in clarifying legal considerations. The behavior of a mixture may be considered in terms of a phase diagram of the type shown in Fig. 2, but known to be of different proportions.

Assume a well in a reservoir having fluid thought to be below its critical temperature, or below the pressure of maximum temperature on the phase diagram, for a representative reservoir fluid. The well could be producing from the reservoir a uniform phase: (1) above the liquid line of its diagram, (2) saturated liquid, or (3) a mixture of vapor and liquid. In any event the volume of the liquid in the reservoir would diminish upon pressure reduction. A well in the first two cases could produce uniform fluid only but in the third could give almost any gas-liquid ratio. The behavior of the well effluent at the surface that produces only from the vapor phase or produces a mixture of the two reservoir phases must be considered in the light of a phase diagram for the new mixture. In most cases a saturated reservoir vapor would be at some point on its phase diagram between critical temperature and maximum temperature, and would give retrograde condensation if the separator conditions were chosen to give a pressure-temperature point within the diagram. The position of the saturated vapor on its own diagram must be relatively close to the maximum temperature value for 2000 to 3000-lb. gas wells producing a condensate with high gas-oil ratios, since a high value for percentage of liquid is not traversed in the expansion process. If the well produced a mixture of the two reservoir phases, the new mixture might be at its critical temperature, but at a pressure low enough to show nothing but normal vaporization with pressure decrease.

For conditions above the critical temperature but below maximum two-phase temperature, and above the pressure for this temperature, a reservoir fluid might be in the uniform fluid phase or be a mixture of vapor and liquid. If it were a uniform phase, pressure reduction would cause liquefaction to a degree dependent upon the relation of the temperature to the critical and maximum temperatures. For conditions above the maximum temperature a uniform phase exists for any pressure, hence this condition is not likely to occur for fluids containing substantial amounts of compounds above hexane or heptane.

Conclusions

We have not accumulated enough data for drawing definite conclusions concerning the critical phenomena as applied to all gas and oil mixtures. Data presented showed that hydrocarbon vapors may give gas-

liquid ratios of 5000 to 10,000 cu. ft. per barrel of liquid and that ratios for saturated liquids are unlikely to pass 5000 cu. ft. per barrel of residual liquid for any natural fluid. Critical temperatures of mixtures are defined and shown to have little significance if the pressure is appreciably below the critical pressure. Retrograde condensation may occur upon isothermal expansion of vapors coming from a two-phase system below its critical temperature, because the vapors must be considered in terms of the phase diagram after removal from the two-phase system and hence be above the critical temperature.

The gradual changes that occur upon compression of the gaseous and liquid phases before critical conditions are reached should be of interest to production groups because the data presented point to critical pressures above 10,000 lb. for mixtures void of excess intermediate constituents between methane and the high-boiling compounds. For more volatile mixtures, critical pressures may occur in the range of reservoir pressures found in deep wells. The increased concentration of gaseous constituents in the liquid phase may be expected to eliminate the tar constituents of the liquid produced.

Acknowledgments

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Gravitational Concentration Gradients in Static Columns of Hydrocarbon Fluids

By B. H. Sage,* Member A.I.M.E., and W. N. Lacey*

(Los Angeles Meeting, October, 1938)

Variations in the composition of the liquid phase of natural reservoirs which are continuous through significant ranges in elevation have been noted by petroleum technologists. In general, there is a greater gas-oil ratio and the gravity of the oil is higher in production from the upper parts of the formation. In the present paper the possible changes in composition with elevation which would result from the attainment of thermodynamic equilibrium in a uniform gravitational field have been evaluated for a naturally occurring hydrocarbon liquid, a binary hydrocarbon liquid phase and a binary hydrocarbon gas. The results indicate a progressive decrease in the mole fraction of the components from methane through the butanes with increasing depth, accompanied by a corresponding increase in the amount of the heavier components making up the system. The magnitude of these variations is perhaps insufficient to explain completely the variations in the properties of the liquid phase that are encountered at various elevations within a particular producing horizon. However, the changes are significant and the treatment presents an example of the application of thermodynamic data to the evaluation of the properties of hydrocarbon fluids under the conditions approaching those encountered in natural reservoirs.

Theoretical Considerations

Muskat[1] has discussed the work of earlier authors relating to the equilibrium relationships of multicomponent systems in a gravitational field. He also presented explicit solutions for several cases and discussed the physical significance of gravitational concentration gradients.

In engineering work it is customary to consider the pressure, the temperature and the composition of a phase to be the independent variables sufficient to establish its state. This procedure neglects the effect of gravitational or other types of fields upon the energy associated with the system and assumes, among other things, that the pressure is uniform in

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[1] References are at the end of the paper.

all parts of the system. If it is desired to introduce the effect of gravity, it becomes necessary to change the constant in the phase rule from 2 to 3, and the rule may then be stated by the following equation:

$$f = c - p + 3 \tag{1}$$

Under these circumstances it is seen that the stipulation of $n + 2$ variables is required to define the state of a one-phase n-component system. In the

Nomenclature

c = number of components.
$\underline{E}$ = internal energy, B.t.u.
E_k = partial molal internal energy, $\left(\frac{\partial \underline{E}}{\partial m_k}\right)_{T,P,m_i}$, B.t.u. per mole.
$\underline{F}$ = thermodynamic potential or free energy, $\underline{E} + P\underline{V} - T\underline{S}$, B.t.u.
F_k^* = molal thermodynamic potential of component k in the pure state at infinite attenuation.
F_k = chemical potential or partial molal free energy $\left(\frac{\partial \underline{F}}{\partial m_k}\right)_{T,P,m_i}$ B.t.u. per mole.
f = degrees of freedom.
h = elevation above an arbitrarily chosen datum, feet.
M = average molecular weight.
M_k = molecular weight of component k.
m_k = moles of component k.
n = mole fraction of any component.
n_k = mole fraction of component k.
P = pressure, lb. per sq. in. absolute.
p = number of phases.
R = universal gas constant.
$\underline{S}$ = entropy, B.t.u. per deg. F. absolute.
S_k = partial molal entropy of component k; $\left(\frac{\partial \underline{S}}{\partial m_k}\right)_{T,P,m_i}$; B.t.u. per deg. F. absolute per mole.
T = temperature (thermodynamic scale), deg. F. absolute.
$\underline{V}$ = volume, cu. ft.
V = molal volume, cu. ft. per mole.
$\bar{V}_k$ = partial molal volume $\left(\frac{\partial \underline{V}}{\partial m_k}\right)_{T,P,m_i}$, cu. ft. per mole.
$\underline{\bar{V}}_k$ = residual partial molal volume $\left(\frac{\partial \underline{V}}{\partial m_k}\right)_{T,P,m_i}$, cu. ft. per mole.
w' = work done by the system during an infinitesimal change in state, exclusive of that resulting from a change in volume, B.t.u.
ln = natural logarithm.

Subscript a denotes all components in an n component system.
Subscript k denotes any component from 1 to n.
Subscript i denotes all components except component k.
Subscript j denotes any component except components k and n.
Subscript m denotes all components except components k and n.
Subscript q denotes all components except components j and n.

present discussion these will be assumed to be the pressure,* the temperature, the mole fractions of $n - 1$ components and the elevation (above some arbitrarily chosen datum) in a continuous column of fluid, subjected to a uniform gravitational field. The values of all of these variables must be related to a given point in the column of fluid.

For a system to be at equilibrium under such conditions it is necessary that the chemical potential (i.e., the partial molal free energy) of each component be equal at all points in the system. This fact may be expressed in the following way:

$$d\bar{F}_k = 0 \qquad [2]$$

In order that the system may be at thermodynamic equilibrium, it is necessary that the temperature of the system be uniform throughout. Since the chemical potential is a function of state, the assumption as to the independent variables makes it a function of the pressure, temperature, elevation and weight fractions of $n - 1$ components. The following equation, based only upon the fundamental relationship of partial differentiation, may then be written for isothermal conditions:

$$d\bar{F}_k = \left(\frac{\partial \bar{F}_k}{\partial P}\right)_{T,h,n_a} dP + \left(\frac{\partial \bar{F}_k}{\partial h}\right)_{T,P,n_a} dh + \left(\frac{\partial \bar{F}_k}{\partial n_k}\right)_{T,P,h,n_m} dn_k + \sum_{j=1}^{j=n-1} \left(\frac{\partial \bar{F}_k}{\partial n_j}\right)_{T,P,h,n_q} dn_j \qquad [3]$$

From equations 2 and 3, the change in composition necessary to compensate for the corresponding changes in the chemical potential with pressure and elevation under isothermal conditions may be evaluated. However, it is necessary to determine the change in the chemical potential with respect to pressure and elevation in terms of measurable quantities before quantitative values of $\left(\frac{\partial n_k}{\partial h}\right)_T$ may be obtained.

The chemical potential may be defined partly[2] by means of the relationship:

$$\bar{F}_k = \bar{E}_k - T\bar{S}_k + P\bar{V}_k \qquad [4]$$

If this is differentiated for a constant temperature, the following equation is obtained:

$$d\bar{F}_k = d\bar{E}_k - Td\bar{S}_k + Pd\bar{V}_k + \bar{V}_k dP \qquad [5]$$

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* The calculations in this paper have been based upon the engineers' system of units involving force, length and time. The mole (pound molecular weight) has been used as the unit of mass. A standard acceleration of 32.17 feet per second per second has been assumed.

From the laws of thermodynamics, a general expression may be written for a reversible change in state at constant pressure and temperature:

$$Td\bar{S}_k = d\bar{E}_k + Pd\bar{V}_k + w' \tag{6}$$

In equation 6 the term w' is any work done by the system (in this case, the component) exclusive of that resulting from its change in volume, which is accounted for by the term $Pd\bar{V}_k$. If equations 5 and 6 are combined, a relationship is obtained between the change in the chemical potential and the change in pressure and the work done by the system:

$$d\bar{F}_k = \bar{V}_k dP - w' \tag{7}$$

If equation 7 is restricted to changes in state occurring under isobaric, isothermal conditions, a relationship between the change in the chemical potential and the work done other than by volume change is obtained:

$$d\bar{F}_k = -w' \tag{8}$$

The work w' that is involved in changing the elevation of a mole of component k at a constant pressure and temperature* is indicated by the following expression:

$$-w' = M_k dh \tag{9}$$

The rate of change of the chemical potential with elevation is related to the molecular weight of the component in the following way:

$$\left(\frac{\partial \bar{F}_k}{\partial h}\right)_{T,P,n_a} = M_k \tag{10}$$

The change in the chemical potential with pressure is related to the partial molal volume of the component by means of the following general thermodynamic expression, which follows from equation 7, since, in the present discussion, w' is equal to zero when h is constant:

$$\left(\frac{\partial \bar{F}_k}{\partial P}\right)_{T,h,n_a} = \bar{V}_k \tag{11}$$

The change in pressure with respect to the elevation may be ascertained from a knowledge of the molecular weight and the molal volume of the phase as a whole. This relationship is indicated in the following equation for a phase acted upon by a standard uniform gravitational field:

$$\frac{dP}{dh} = -\frac{M}{V} \tag{12}$$

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* This implies that the change in elevation of the component occurs in such a fashion that no friction is involved. In this connection friction may be defined as a transfer of mechanical energy into some other form of energy as the result of movement of parts of the system relative to each other or to the boundary.

If the foregoing expressions are combined with equations 2 and 3, a relationship between the isothermal change in composition with elevation and measurable properties of the phase is obtained:[3]

$$\left(\frac{\partial n_k}{\partial h}\right)_T = \frac{\dfrac{M\bar{V}_k}{V} - M_k - \displaystyle\sum_{j=1}^{j=n-1}\left(\frac{\partial \bar{F}_k}{\partial n_j}\right)_{T,P,h,n_s}\frac{dn_j}{dh}}{\left(\dfrac{\partial \bar{F}_k}{\partial n_k}\right)_{T,P,h,n_m}} \qquad [13]$$

The solution of equation 13 requires a knowledge of the change in the chemical potential with composition. This necessitates a reasonable amount of information concerning the behavior of the system before it is possible to solve equation 13 without simplifying assumptions.

The chemical potential of a component may be evaluated by means of the following expression, in which $F_k{}^*$ is the thermodynamic potential of the component in the pure state and at infinite attenuation, corresponding to pressure P_0. This equation[4] is based upon the assumption of ideal solutions[5] at infinite attenuation, which appears to be adequately justified by the kinetic theory for nearly all systems:

$$\bar{F}_k = RT \ln n_k + \int_{P_0}^{P} \bar{V}_k dP + F_k{}^* \qquad [14]$$

If equation 14 is differentiated with respect to the mole fraction of component k at a constant temperature and pressure, the following relationship is obtained:

$$\left(\frac{\partial \bar{F}_k}{\partial n_k}\right)_{T,P,h,n_m} = \frac{RT}{n_k} + \int_{P_0}^{P}\left(\frac{\partial \bar{V}_k}{\partial n_k}\right)_{T,P,h,n_m} dP \qquad [15]$$

If equation 15 is combined with equation 13, the following relationship between the composition and elevation in a uniform gravitational field of standard intensity is obtained:

$$\left(\frac{\partial n_k}{\partial h}\right)_T = \frac{\dfrac{M\bar{V}_k}{V} - M_k - \displaystyle\sum_{j=1}^{j=n-1}\left(\frac{\partial \bar{F}_k}{\partial n_j}\right)_{T,P,h,n_s}\frac{dn_j}{dh}}{\dfrac{RT}{n_k} + \displaystyle\int_{P_0}^{P}\left(\frac{\partial \bar{V}_k}{\partial n_k}\right)_{T,P,h,n_m} dP} \qquad [16]$$

At present information is not available concerning either the partial molal volumes of the components throughout the entire range of pressures or the changes in the chemical potential of the components with variation of the composition of multicomponent systems. It is necessary, therefore, to make simplifying assumptions in order to obtain a solution to equation 16 in many of the cases that are of interest in petroleum practice.

If it is assumed that the system in question follows the behavior of an ideal solution[5] at all pressures for the temperature in question, equation 16 reduces to the following relationship, since the chemical potential of a component is then independent of the nature and relative proportions of the other components present and the partial molal volume of a component is independent of its mole fraction:

$$\left(\frac{\partial n_k}{\partial h}\right)_T = \frac{n_k}{RT}\left(\frac{M\bar{V}_k}{V} - M_k\right) \qquad [17]$$

It should be realized that this discussion has related to the case in which the system is at uniform temperature throughout. The actual case in an underground formation or in a shut-in well is characterized by a temperature variation with elevation. Such a system cannot be treated fully by the methods used above. However, it is the belief of the authors, from considerations apart from thermodynamics, that the effects estimated from the isothermal case would be enhanced rather than compensated by the presence of the temperature gradients found in practice.

Results

As is indicated in equation 17, a knowledge of the molal volume and molecular weight of the phase and the partial molal volume of the component, together with the assumption of ideal solution behavior at all pressures for the temperature in question is sufficient to permit the calculation of the change in mole fraction of the component with elevation. A correlation of the partial volumetric behavior of the lighter hydrocarbons in the liquid phase is available[6] and permits the evaluation of the necessary partial molal volumes. In order to illustrate the magnitude of these effects in naturally occurring hydrocarbon liquid phases, a mixture of crude oil and natural gas from the Dominguez field in California was chosen as one of the materials for which the gravitational concentration gradients were to be estimated. Experimental data[7] are available concerning the molal volumes of liquid mixtures of these materials together with information concerning the composition of the liquid phase.

The composition of the liquid phase at the gas-liquid interface and the values of $\left(\frac{\partial n_k}{\partial h}\right)_T$ calculated from equation 17 for several pressures at a temperature of 160°F. are recorded in Table 1. Values of $\left(\frac{\partial n_k}{\partial h}\right)_T$ have been calculated for methane, ethane, propane and the butanes. The depths—i.e., negative elevations—corresponding to the pressures indicated in Table 1 were computed by suitable application of equation 12. Graphic evaluation of $\int\left(\frac{\partial n_k}{\partial h}\right)_T dh$ yields values of the composition at a

series of depths, which are recorded in Table 2. In this instance the elevation was taken as zero at the gas-liquid surface, where the composition corresponded to the experimentally determined phase behavior recorded in Table 1. The mole fractions of the components from methane

TABLE 1.—*Calculated Isothermal Gravitational Gradients in a Liquid Mixture of Natural Gas and Crude Oil at* 160° *F.*

Pressure, Lb. per Sq. In. Abs.	$\left(\frac{\partial n_k}{\partial h}\right)_T \times 10^6$				
	Methane	Ethane	Propane	Butanes	Heavier
	(0.227)[a]	(0.0099)	(0.0088)	(0.0053)	(0.749)
1115[b]	6.54[c]	0.176	0.204	0.142	−7.06
1500	6.16	0.171	0.199	0.139	−6.67
2000	5.69	0.166	0.193	0.135	−6.18
2500	5.25	0.160	0.187	0.133	−5.73
3000	4.80	0.155	0.183	0.131	−5.27

[a] Figures in parentheses are the composition of the liquid phase at the liquid-gas interface, expressed as mole fraction.

[b] Bubble-point pressure, lb. per sq. in. abs.

[c] Concentration gradient expressed as the change in mole fraction per foot change in elevation.

TABLE 2.—*Calculated Composition of Liquid Phase of Mixture of Natural Gas and Crude Oil as a Function of Depth at* 160° *F.*

Depth,[a] Ft.	$n_k \times 10^2$				
	Methane	Ethane	Propane	Butanes	Heavier
0	22.71[b]	0.990	0.870	0.518	74.91
1000	22.07	0.973	0.850	0.504	75.61
2000	21.47	0.956	0.830	0.490	76.25
3000	20.89	0.939	0.811	0.476	76.88
4000	20.36	0.923	0.792	0.463	77.46
5000	19.85	0.907	0.774	0.450	78.02
6000	19.37	0.892	0.755	0.437	78.55

[a] Measured from liquid-gas interface.

[b] Expressed in terms of mole fraction.

through the butanes as a function of depth below the liquid-gas interface are depicted in Fig. 1. These results indicate a progressive decrease in the mole fraction of the lighter components with an increase in depth below the gas-liquid interface. The gravitational composition gradients are not large but are significant when large changes in elevation are encountered. From a consideration of equation 17, it is seen that the negative rate of change of the mole fraction of a component with depth

is directly proportional to its mole fraction and increases rapidly with an increase in the partial molal volume of the component in question above the molal volume of the phase as a whole.

In order to illustrate the magnitude of the change in composition with elevation, which may be encountered in hydrocarbon liquids of higher A.P.I. gravity than that involved in the first illustration, the gravitational gradients in another hydrocarbon system were estimated. In Table 3 are recorded values at 160° F., of the composition of a liquid mixture of methane and n-butane* containing 28.7 mole per cent methane. In this

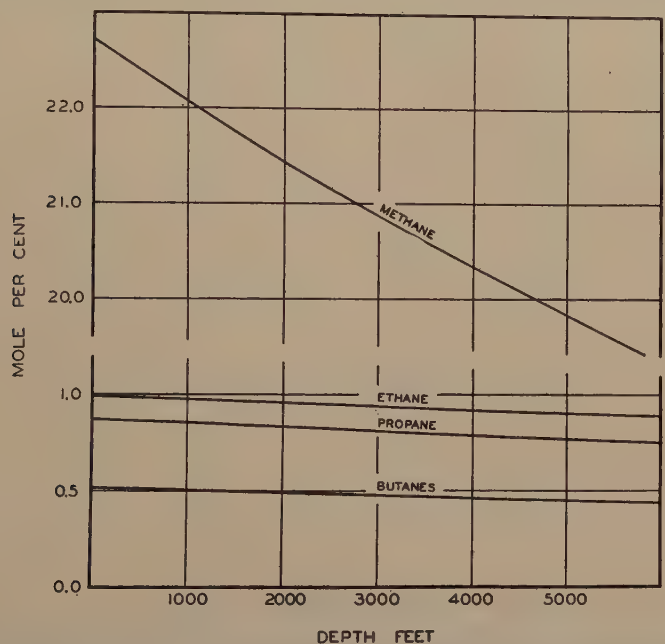

FIG. 1.—CALCULATED EFFECT OF DEPTH UPON COMPOSITION OF LIQUID MIXTURE OF CRUDE OIL AND NATURAL GAS AT 160° F.

instance the partial molal volume of methane is somewhat larger than was encountered in natural gas and crude oil. This accounts for the much larger decrease in the mole fraction of methane with depth than is shown for that case in Fig. 1. This difference in behavior is indicated in Fig. 2, which shows for comparison the mole fraction of methane in the liquid phase of the methane-butane system and in the natural gas-crude oil system as a function of depth for a temperature of 160° F.

It must be realized that the information thus far presented is based upon equation 17, which involves the assumption of ideal solutions at all

* Experimental measurements made by the authors relating to the volumetric behavior of mixtures of methane and n-butane in the liquid phase have not as yet been published.

pressures for each of the components in question. This assumption involves uncertainty in regard to both of the systems reported but describes the effect of gravity upon composition gradients as well as it is possible to do with existing experimental information. It is difficult to estimate just how large the uncertainty may be, but it may amount to as much as 25 per cent in the methane-butane system, which is not far distant from the critical state at the pressures, temperatures and compositions involved in the data recorded in Table 3. However, it is believed that the results are qualitatively indicative of the magnitude

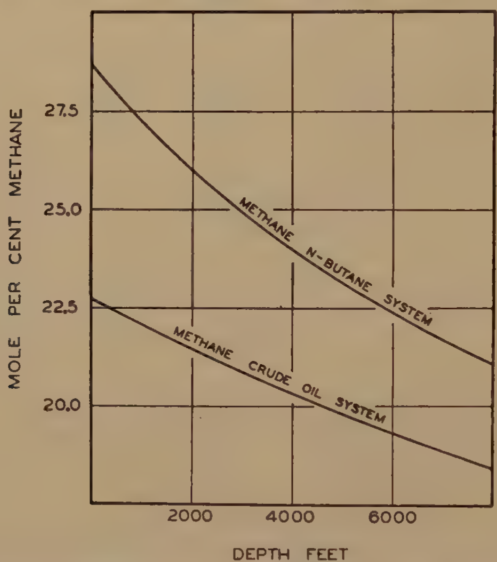

FIG. 2.—CALCULATED EFFECT OF DEPTH UPON COMPOSITION OF LIQUID MIXTURE OF METHANE AND N-BUTANE AT 220° F.

of the changes in composition with elevation that are encountered at thermodynamic equilibrium in a uniform gravitational field.

Similar effects are involved in static gas columns when at equilibrium. If information concerning the effect of pressure, temperature and composition upon the molal volume of the system in question is available from infinite dilution to the pressure in question, the composition gradient may be established without assuming ideal solution behavior. For this purpose equation 16 may be used. However, the direct evaluation of $\int_{P_0}^{P}\left(\frac{\partial \bar{V}_k}{\partial n_k}\right)_{T,P,h,n_m} dP$ is difficult and residual methods simplify the procedure. The residual partial molal volume $\underline{\bar{V}}_k$ is related to the partial molal volume of the component in the following way:

$$\underline{\bar{V}}_k = \frac{RT}{P} - \bar{V}_k \qquad [18]$$

TABLE 3.—*Calculated Composition of Liquid Phase of a Mixture of Methane and n-Butane as Function of Depth at 220° F.*

Depth,[a] Ft.	Pressure, Lb. per Sq. In. Abs.	$\left(\frac{\partial n_1}{\partial h}\right)_T \times 10^6$	Methane
0	1138[b]	15.4[c]	0.2870[d]
1000	1300	13.4	0.2727
2000	1466	11.6	0.2602
3000	1640	10.2	0.2494
4000	1816	8.91	0.2400
5000	1997	7.86	0.2316
6000	2180	7.01	0.2242
7000	2367	6.33	0.2174
8000	2556	5.72	0.2114
9000	2750	5.20	0.2060
10000	2945	4.72	0.2011

[a] Measured from liquid-gas interface.
[b] Bubble point pressure.
[c] Concentration gradient expressed as change in mole fraction of methane per foot change in elevation.
[d] Expressed as mole fraction.

If equation 18 is differentiated with respect to the mole fraction of component k, the following relationship is obtained:

$$\left(\frac{\partial \underline{\bar{V}}_k}{\partial n_k}\right)_{T,P,h,n_m} = -\left(\frac{\partial \bar{V}_k}{\partial n_k}\right)_{T,P,h,n_m} \tag{19}$$

If equation 19 is combined with equation 16, there results for a binary system:

$$\left(\frac{\partial n_k}{\partial h}\right)_T = \frac{\frac{M\bar{V}_k}{V} - M_k}{\frac{RT}{n_k} - \int_{P_0}^{P}\left(\frac{\partial \underline{\bar{V}}_k}{\partial n_k}\right)_{T,P,h,n_m} dP} \tag{20}$$

This equation may be used conveniently for the evaluation of the change in composition with elevation since the value of $\underline{\bar{V}}_k$ is finite at infinite attenuation. The value of $\left(\frac{\partial \underline{\bar{V}}_k}{\partial n_k}\right)_{T,P,h,n_m}$ can be obtained by graphical differentiation of the relationship of $\underline{\bar{V}}_k$ with respect to the mole fraction of component k. The values of $\underline{\bar{V}}_k$ can be established from experimental pressure-volume-temperature measurements by the use of residual methods in connection with the procedure outlined by Roozeboom.[8]

Values of $\left(\frac{\partial n_k}{\partial h}\right)_T$ are recorded in a part of Table 4 as a function of the pressure for a gaseous mixture of methane and n-butane, at a temperature

of 160° F., containing 89.4 mole per cent methane at zero elevation. The pressure gradient in the static column of gas was established by suitable application of equation 12. The variation in the composition of the system with elevation was then established by graphic evaluation of $\int \left(\frac{\partial n_k}{\partial h}\right)_T dh$ assuming a pressure of 500 lb. per sq. in. at the elevation datum. The results of this calculation are recorded in a part of Table 4. The change in composition is somewhat greater than was encountered in

Table 4.—*Calculated Composition of Gas Phase of a Mixture of Methane and n-butane as Function of Depth at* 160° *F.*

Depth, Ft.	Pressure, Lb. per Sq. In. Abs.	$\left(\frac{\partial n_1}{\partial h}\right)_T \times 10^6$	Methane
0	500	5.25[a]	0.8941[b]
1000	514	5.27	0.8888
2000	528	5.29	0.8835
3000	542	5.31	0.8782
4000	556	5.33	0.8729
5000	570	5.35	0.8675
6000	584	5.37	0.8622
7000	598	5.39	0.8568
8000	612	5.41	0.8514
9000	626	5.42	0.8460
10000	640	5.44	0.8406

[a] Concentration gradient expressed as change in mole fraction of methane per foot change in elevation.

[b] Expressed as mole fraction.

liquids, since there is a large difference between the partial molal volume of methane and the molal volume of the mixture. In this instance no assumptions are involved and it is believed that the values of composition recorded in Table 4 are quantitatively indicative of the concentration gradients in an isothermal static column of hydrocarbon gas of the above-mentioned composition when equilibrium has been established in a uniform gravitation field. However, because of experimental uncertainties in the evaluation of $\left(\frac{\partial \bar{V}_k}{\partial n_k}\right)_{T,P,h,n_m}$, it is possible that errors as great as 10 per cent may exist in the changes of composition recorded in Table 4.

Again it must be emphasized that the magnitude of these gravitational effects is related to the differences between the molal volume of the system and the partial molal volume of the component in question. This results in large gradients in the neighborhood of the critical state where the values of partial molal volumes of nearly all of the components are large positive or negative numbers. Many of the newer fields yielding

materials of high gas-oil ratio at high pressures are probably producing from reservoirs at conditions not greatly removed from the critical states of the systems involved. Under these conditions it is to be expected that gravitational gradients many times those indicated in Tables 2, 3 and 4 will be encountered. As more experimental information accumulates, it will be possible to predict these gradients for naturally occurring hydrocarbon liquids without assuming ideal solution behavior, as was done in this case. It should then be possible to determine these gradients with

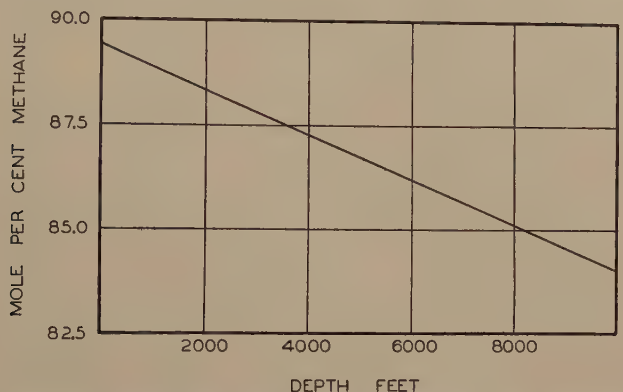

FIG. 3.—CALCULATED EFFECT OF DEPTH UPON COMPOSITION OF GASEOUS MIXTURE OF METHANE AND N-BUTANE AT 160° F.

satisfactory accuracy in close proximity to the critical state where they may be of engineering importance.

ACKNOWLEDGMENTS

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Physical Properties of Hydrocarbons and Their Mixtures

By E. R. Gilliland,* R. V. Lukes* and H. W. Scheeline*

(San Antonio Meeting, October, 1938)

Knowledge of a large number of the physical properties of the hydrocarbons is needed in the calculations and studies of the production engineer. Since experimental data on these properties of the individual hydrocarbons and their mixtures are available in only a relatively few cases, the use of generalized correlations has developed rapidly in the last decade. The generalized correlations of pressure, volume and temperature,[1] enthalpy,[2] and vapor-liquid equilibria,[3] on the basis of reduced temperatures and pressures, are outstanding examples of this development. These correlations are of particular value to the production engineer interested in the flow of oil and gas, since they can be used to estimate the conditions under which segregation of phase occurs as well as the composition, density, and relative amounts of the phases. The technique of using the correlations for such estimations has been published by several authors[4] and will not be considered in this paper. A considerable number of data have been obtained to check the generalized pressure-volume-temperature correlations, and these data indicate that such relations hold for the hydrocarbons from methane to heptane. The accuracy is in general sufficient for most engineering pressure-volume-temperature calculations. However, the generalized correlations of enthalpy and vapor-liquid equilibria have in general been developed from the pressure-volume-temperature correlations by thermodynamic calculations and only a relatively few experimental data are available to check these calculated values. The calculations from pressure, volume and temperature are likely to lead to large errors in the calculated enthalpy and vapor-liquid equilibria. Thus, in the calculations of enthalpies, slopes of the pressure-volume-temperature data are employed, and determining these slopes can greatly amplify small errors in the original data. In the vapor-liquid equilibria calculations it is necessary to have the pressure-volume-temperature relations of the mixture, and the latter properties are much more questionable than those of pure components, particularly in the critical region. A considerable number of experimental data are

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[1] References are at the end of the paper.

needed to check the accuracy and increase the utility of these correlations. This paper presents a preliminary report of the apparatus being used and some of the results obtained at the Massachusetts Institute of Technology. In all cases this work is being particularly directed to the study of the mixtures rather than of pure components. However, in the study of mixtures, certain problems arise such as the difficulty of obtaining a number of pure hydrocarbon components of known physical properties and the difficulty involved in the accurate analysis of such mixtures. For these reasons mixtures containing not over three or four pure components appear to be the most promising at the present stage of development.

Vapor-liquid Equilibria

In numerous operations of the petroleum industry, vapor and liquid phases are encountered in contact with each other. For the calculations related to such operations it is frequently necessary to be able to estimate or predict the relative composition of the two phases. The most widely used method of predicting such vapor-liquid equilibria for hydrocarbon mixtures at elevated pressures involves the use of the so-called equilibrium constants. These equilibrium constants have been based to a large extent on fugacities, calculated from pressure-volume-temperature data on the pure hydrocarbons, and have been expertly modified to fit the small amount of available experimental equilibria data. The success of such correlations has been outstanding. However, a little consideration indicates that such generalized equilibrium constants for a given substance independent of the other components present cannot be valid at pressures high enough to approach the critical of the mixture, since at the critical conditions the equilibrium constants must approach unity whereas the critical temperature and pressure of a mixture depend not only on the component in question but also on the physical nature of the other components and their relative amounts. It is necessary, therefore, for the equilibrium constant for a given component to be unity at different temperatures and pressures, depending on the other components present and their amounts. In other words, at pressures approaching the critical range, the relation between the mole fraction of a component in the vapor and liquid at a given temperature and pressure must be a function of the other components present, and the values calculated from the pressure-volume-temperature data for the pure components must become in error. If accurate pressure-volume-temperature data were available on the mixtures as well as on the pure components, these computations could be accurately extended into the high-pressure region. However, few data are available on the pressure-volume-temperature relations of mixtures at high pressures, and empirical rules for the estimation of these data in their present state are not sufficiently accurate to serve as a basis for the calculations of vapor-liquid equilibria.

Experimentally, two general methods have been used for determining such vapor-liquid equilibria at high pressure. The dew-point, bubble-point method has been used by a number of investigators.[5] In this method the dew point and bubble point of a number of binary mixtures are determined at various pressures. For each composition, the dew-point and bubble-point curves are plotted as a function of pressure, and where a dew-point curve for one composition crosses a bubble-point curve for another composition, the composition of the dew-point curve is the vapor in equilibrium with liquid of the composition of the bubble-point curve at the pressure and temperature of the intersection. Such a method has the advantage that the samples to be tested can be made of known compositions, but it has the disadvantage that the accurate determination of dew points and bubble points is generally difficult and such determinations are seriously affected by small traces of impurities having volatilities different from the two main components. It has the further drawback that it is limited to binary mixtures, since for mixtures of more components the same dew point and bubble point can be obtained at a given pressure for an infinite number of mixtures. Thus the intersection at a given temperature and pressure, instead of corresponding to one vapor composition and one liquid composition, as for binary mixtures, now corresponds to an infinite number of vapor and liquid compositions and it is impossible to determine which vapor composition is related to any liquid composition.

Another method of determining such equilibria has been to place the two phases in a bomb maintained at constant temperature and pressure, and obtain equilibrium by agitation. Samples of the vapor and liquid phase are then withdrawn and analyzed. In this method, it is necessary to prevent a reduction in pressure while sampling, and this is generally accomplished by adding to the bomb mercury equivalent to the volume of the sample removed. Precautions must also be taken to prevent liquid from entering the vapor sample line and thereby contaminating the vapor sample.

One of the most satisfactory methods of obtaining vapor-liquid data at atmospheric pressure and lower is by the so-called equilibrium still.[6,7] In the present work this still has been adapted to high pressures. In the low-pressure equilibrium stills, the pressure is maintained by sealing the condenser with an inert gas, usually air, which automatically maintains constant pressure by sealing off the portion of the condenser that is not necessary for heat removal. At high pressures such a method of pressure control is not satisfactory because the solubility of the pressure-control gas becomes so high in the condensate that the equilibrium conditions are modified. The high-pressure equilibrium still therefore was constructed to operate without an inert gas, but in order to maintain constant pressure under such conditions it was necessary to make the heat input exactly

equal to the heat output. This balance of input to output was maintained electrically by a mercury manometer control. It was also found to be highly desirable to have the still portion of the apparatus constructed of glass, so that the liquid level could be observed. This was particularly desirable near the critical region since the density of the vapor and liquid phases become so nearly equal that wide variations in the liquid level are encountered. A suitable glass for this construction was found in "Sonderglass."

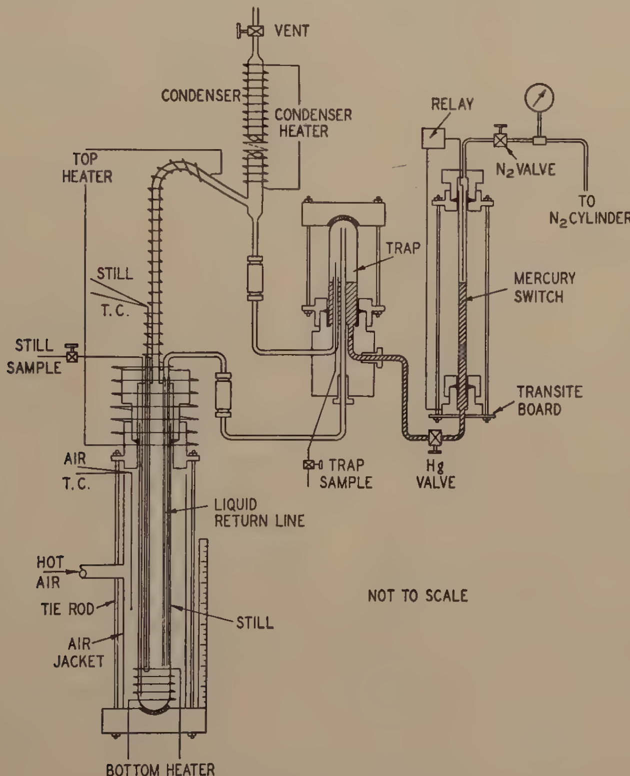

FIG. 1.—EQUILIBRIUM STILL.

The constructional details of the high-pressure still are shown in Fig. 1. The still was of the form of a large test tube closed at the upper end by a metal packing gland which conducted the vapors to the condenser. The condensate flowed to the distillate trap, which was a glass tube similar to the still but of smaller size. A return line carried the condensate from the trap to the still for reboiling. The lower portion of the condensate trap was filled with mercury and this mercury was connected to the mercury manometer, which was balanced against a tank of inert gas at the desired pressure. If the pressure in the equilibrium still tended to rise, mercury was forced from the trap into the manometer and by a

system of relays the heat to the still was reduced, thereby lowering the pressure, and conversely, when the pressure tended to decrease the heat to the still was again increased. Such a control allowed maximum pressure variations of about 1 lb. per sq. in. Entrainment in the apparatus was checked in test runs by adding a dye to the liquid in the still and visually observing the condensate in the trap. Such tests indicated that entrainment was not encountered under the operating conditions employed in the equilibrium determinations. Each equilibrium determination was allowed to run for approximately 2 hr., after which samples were removed from the still and the condensate trap and analyzed.

TABLE 1.—*Vapor-liquid Equilibria Data for Propane-isobutylene Mixtures*

Pressure, Lb. per Sq. In. Abs.	Temperature, Deg. F.	x, Per Cent Mole C_3 in Liquid	y, Per Cent Mole C_3 in Vapor
200	160	19.0	35.9
200	140	45.4	64.8
200	130	57.9	76.0
200	119	75.7	87.7
300	211	9.1	16.8
300	201	18.3	31.3
300	199	19.7	33.7
300	187	30.9	47.3
300	176	46.4	62.3
300	162	64.3	76.0
300	151	77.4	86.5
300	149	83.4	90.3
400	242	8.6	14.0
400	222	28.6	41.3
400	206	43.8	57.2
400	190	64.8	75.4
400	184	73.4	82.7
400	175	84.7	89.5
500	265	10.5	15.1
500	237	35.1	43.4
500	225	48.9	58.3
500	211	66.6	74.1
500	203	76.8	82.3
500	198	85.3	88.9
600	263	29.1	32.8
600	246	49.0	55.6
600	236	59.1	64.7
600	224	74.2	78.4
600	218	79.9	83.0

The results on the system propane-isobutylene are presented in Figs. 2 and 3 and Table 1. Fig. 2 summarizes the vapor-liquid equilibria at 200, 300, 400, 500 and 600 lb. per sq. in. abs. The y-x curves approach the 45° diagonal as the pressure is increased and become discontinuous

above 583 lb. per sq. in., which is the critical pressure of isobutylene. Figs. 4, 5 and 6 show the vapor-liquid equilibrium curves for 200, 400 and 600 lb. per sq. in. together with the curves calculated from the generalized fugacity plots and by Raoult's law. Raoult's law gives values that are too high in all cases; the fugacities give values a little too low at 200 lb. per sq. in., but are in good agreement at 400 lb. per sq. in. At 600 lb. per sq. in. the fugacity curve is considerably too high and fails to show the discontinuity at the lower concentrations. Fig. 3 gives the temperature composition curves for the same three pressures together with the curves calculated by the use of fugacities. The values of the equilibrium constants $K = y/x$ for isobutylene are compared with the fugacity values in Fig. 7. The agreement between the experimental values and those predicted from fugacities is good up to about 300 lb. per sq. in., but at higher pressures the deviations become increasingly greater. In this figure, the experimental curves at 140°, 160°, 180° and 200° F. terminate at pressures corresponding to the vapor pressure of propane at the respective temperature, since this represents the maximum pressure at which any mixture of isobutylene and propane can exist as two phases at these temperatures. At higher pressures only the liquid phase exists in this temperature range. However, at temperatures above 210° F. (the critical temperature of propane) the curves would be continuous up to the critical pressure of the mixture. No data were obtained in this region above 600 lb. per sq. in., but the curves for the temperatures above 210° F. would bend around and come back to $K = 1$ at the critical pressure corresponding to the temperature in question. The values predicted from fugacity calculations are seen to be greatly in error in the higher pressure region, since the values in this region depend on the other components present. Thus different K values for isobutylene would be expected at the same temperature and pressure, depending on what other components were present. However, the data indicate that at pressures below 200 to 300 lb. per sq. in. the K values for isobutylene given by the generalized fugacities will probably be satisfactory for hydrocarbon mixtures that do not contain components differing too greatly in molecular weight or type of structure from isobutylene. In order to improve the generalized K charts, it would be necessary to

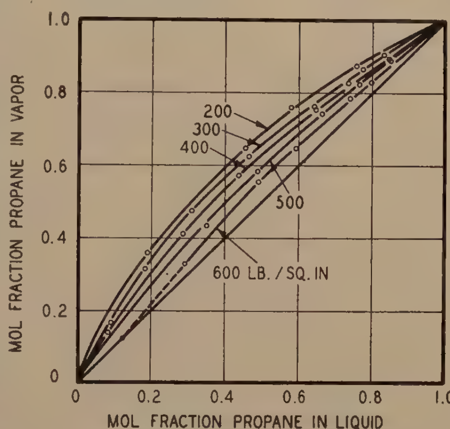

FIG. 2.—RESULTS ON THE SYSTEM PROPANE-ISOBUTYLENE.

estimate the behavior in the high-pressure region as a function of the composition. It would appear that in addition to the K values, as given by the fugacity charts, two main pieces of data are needed in order to approximately predict K values in this region; viz., (1) estimation of the critical pressure of the mixtures as a function of temperature, and (2) estimation of the pressure at which the K values go through a minimum

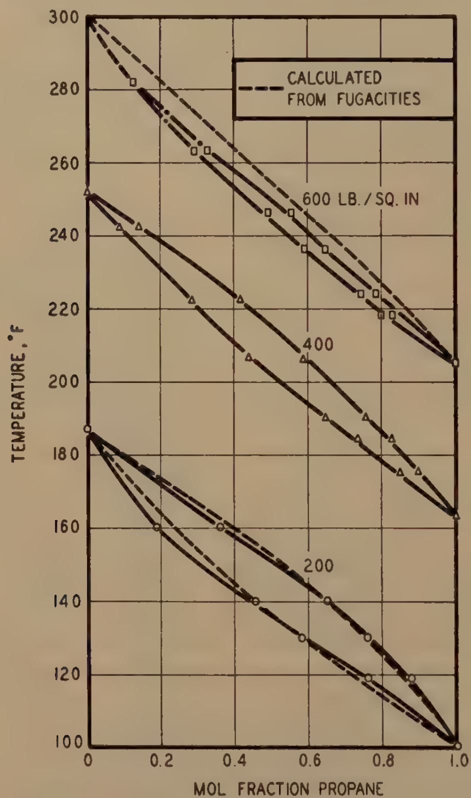

FIG. 3.—RESULTS ON THE SYSTEM PROPANE-ISOBUTYLENE.

at a given temperature. Such information should make it possible to sketch in the curves with sufficient accuracy for most uses.

The corresponding vapor-liquid equilibrium values for propane are given in Fig. 8. In this case a considerably different type of deviation from the predicted K values is encountered. In the temperature range of 160° to 220° F., the experimental and predicted values agree satisfactorily in the high-pressure region, but the predicted values are consistently low at the low pressures. At the higher temperatures the agreement becomes poor, with the experimental and predicted curves crossing at an appreciable angle. The wide deviation in the curves at 280° F. is due to the fact that the critical pressure for a propane-isobutylene mix-

ture at this temperature is about 600 lb. per sq. in. and K must equal 1 at this critical. The deviation at the lower pressures may be due to the fact that a mixture of an olefin and a paraffin tend to deviate more from a perfect solution than would two paraffins. The deviations are in the direction that would be expected for a mixture of two components of the type of polarities of propane and isobutylene.

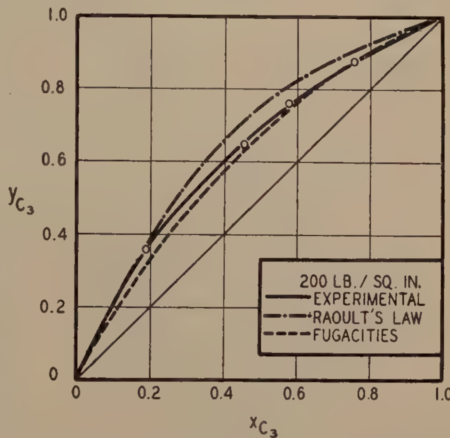

Fig. 4.—Vapor-liquid equilibrium curves.

Enthalpies

The effect of pressure on the enthalpy of hydrocarbon vapors can be fairly large, particularly at high pressures. Thus at the critical temperature an increase in the pressure from atmospheric to the critical pressure can cause a decrease in enthalpy of the vapor equal to about one-third the heat of vaporization of the liquid at atmospheric pressure.

A number of methods of determining these enthalpy changes have been used. As stated earlier in the paper, they can be calculated if accurate pressure-volume-temperature data are available on the system in question. Experimental methods have included the use of the Joule-Thomson expansion and a differential isothermal expansion. The method involved in the present work is the measurement of the isothermal enthalpy change for the expansion from a high pressure to substantially atmospheric pressure. Such a method has a number of advantages, among which are: (1) it gives directly the difference in enthalpy between atmospheric and high pressure at any chosen temperature, (2) the enthalpy change can be measured by the electrical input necessary to maintain isothermal conditions, thereby allowing high precision to be obtained and (3) the heat losses to or from the system can be reduced to a low value since the system is at a constant temperature.

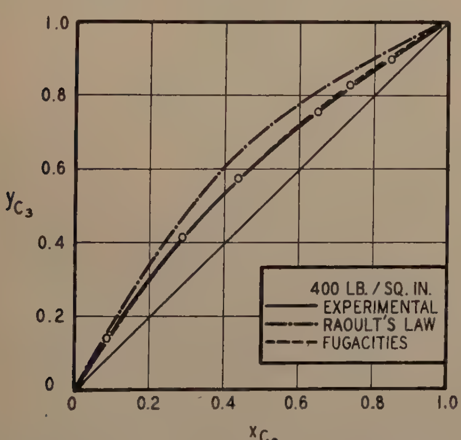

Fig. 5.—Vapor-liquid equilibrium curves.

This isothermal expansion unit is shown in Fig. 9. The general principle involved is the forcing of the material being investigated through a fine capillary tube; the rate of flow and the size of the capillary tube being such that the entire pressure drop from the desired high pressure to substantially atmospheric pressure occurs across the tube. The capillary tube is heated electrically using its own resistance and the electrical input is so regulated that the material enters and leaves the unit at the same temperature. With adequate provision to prevent heat from flowing into or out of the system, the electrical input measures the enthalpy change directly for the rate of material flow in question.

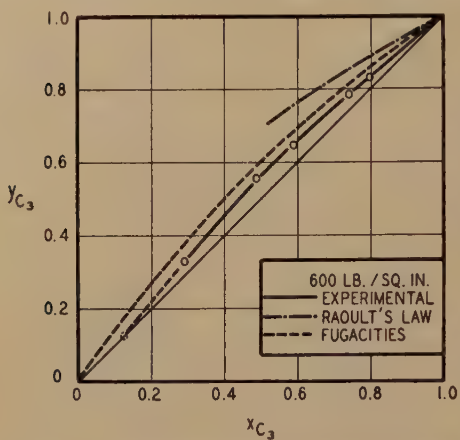

Fig. 6.—Vapor-liquid equilibrium curves.

The actual details of this expansion unit are shown in Fig. 9. The hydrocarbon enters under pressure into the left-hand side of the cross at

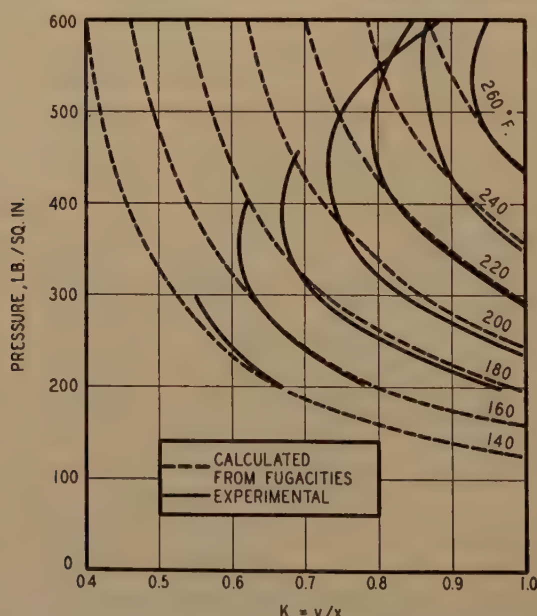

Fig. 7.—Equilibrium constants for isobutylene.

the top, and flows downward in the annular space around the thermocouple well, and the entering temperature is determined at this point.

The other arm of the cross connects through a mercury seal to a dead-weight piston gauge, which serves to measure the pressure. After passing the thermocouple well the hydrocarbon enters the expansion capillary and in passing through drops to essentially atmospheric pressure at the lower end of the capillary. The expanded hydrocarbon vapor then passes up around the capillary and inside the first radiation shield. A little above the upper level of the capillary the vapor reverses flow and passes downward between the first and second radiation shields. At the bottom the flow is again reversed and the vapor passes up the annular space between the second radiation shield and the shell of the unit. The vapor then passes through the exit pipe around the exit thermocouple well, at which point its temperature is again measured. The electrical energy for heating is supplied by the current flowing through the electrical resistance of the 18-8 stainless-steel capillary. Since heat is being transferred to the gas, the capillary must be at a higher temperature than the temperature at which the enthalpy change is being investigated. Because of its higher temperature the capillary would tend to dissipate heat by radiation to the surroundings, and it is the function of the radiation shields to intercept this radiant energy and transfer it to the flowing vapors, and thereby prevent heat loss to the surroundings.

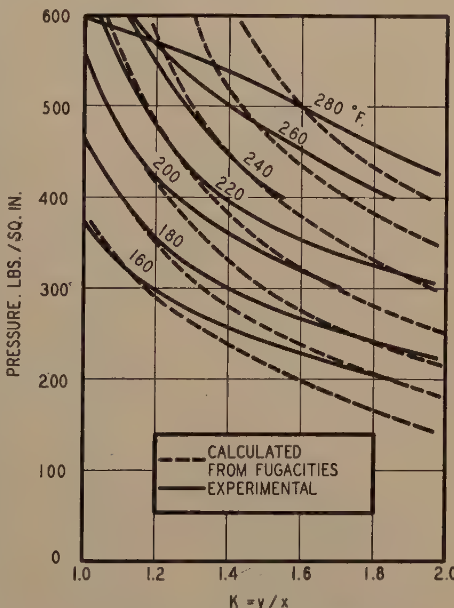

FIG. 8.—EQUILIBRIUM CONSTANTS FOR PROPANE.

In order to obtain the desired rates of flow with varying inlet pressures and operating temperatures, it was necessary to use capillaries of different sizes. The capillaries were 18-8 chrome-nickel steel hypodermic-needle tubing, 0.013 in. inside diameter by 0.025 in. outside diameter, and five different tubes of lengths 1, 3, 5, 8 and 12 ft. were used. These tubes were coiled on arbors varying from ⅛ to 13⁄32 in. and then were sprung to the proper length to fit the expansion unit.

The thermal isolation of the system from the surroundings was effected as shown in Fig. 10. The isothermal expansion unit is shown in the center of the diagram inserted in the copper liner, which was insulated by magnesia lagging from the hollow aluminum cylinder. The aluminum cylinder was wound with an electrical heater and then further insulated.

By maintaining the aluminum cylinder at approximately the same temperature as the expansion unit, such a low-temperature difference existed across the lagging between the cylinder and the expansion unit

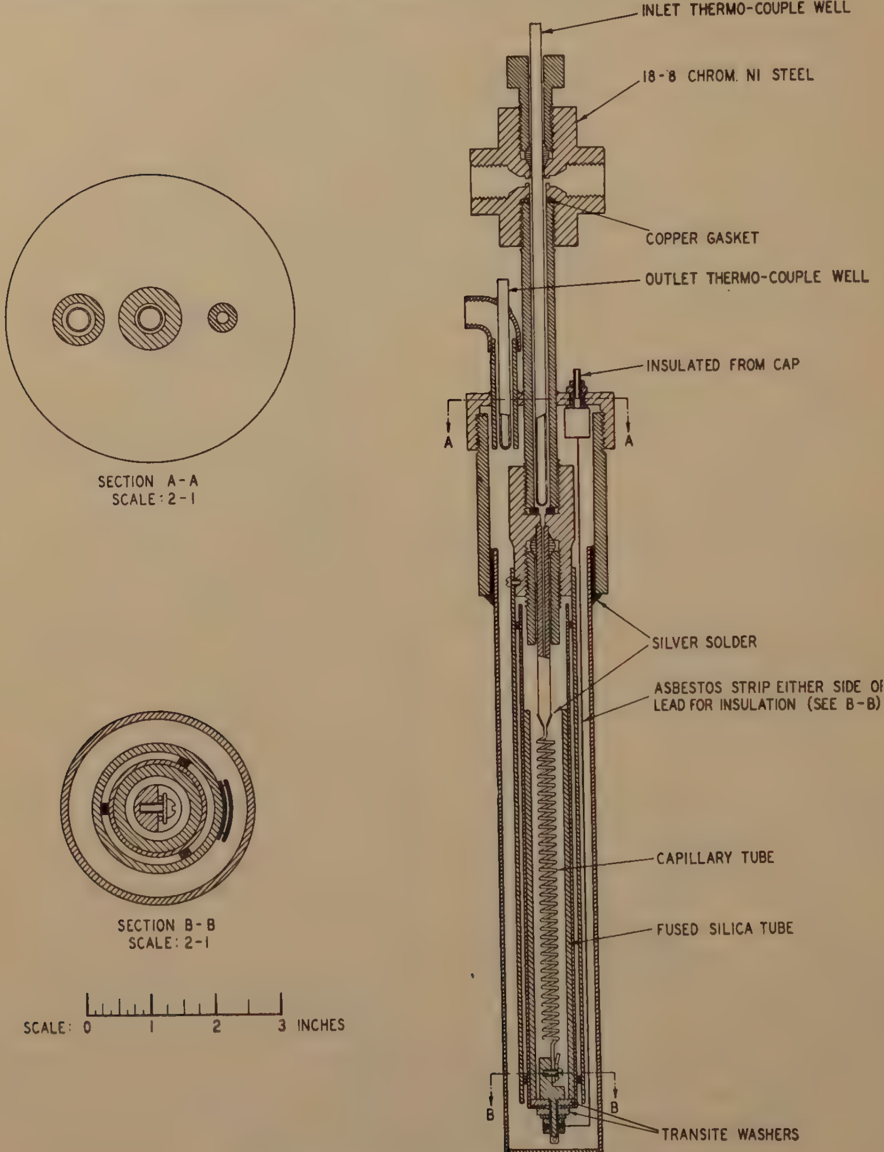

FIG. 9.—ISOTHERMAL EXPANSION UNIT.

that the heat flow was negligible. The exit lead to the condenser, the dead-weight connection lead, and the thermocouple leads were taken out through a heated section to prevent heat loss by conduction.

The flowsheet including the auxiliary apparatus is shown in Fig. 11. The hydrocarbon being tested was stored in A and was pumped by pump D to one side of the reservoir F, from which it flowed through preheater P and R to the isothermal expansion unit of Fig. 9. After leaving the expansion unit the vapor passed to the condensing system and then returned to the storage A. In order to maintain constant flow it was necessary that the inlet pressure to the capillary be maintained constant.

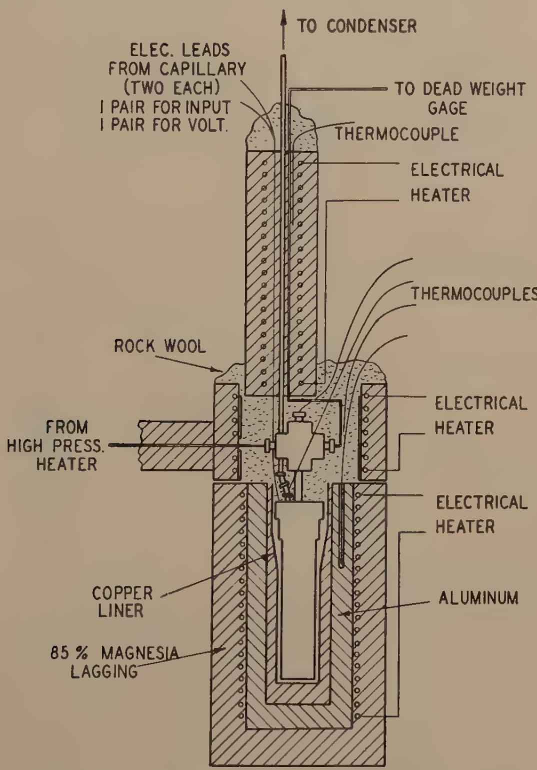

Fig. 10.—Expansion unit with insulation.

This constancy of pressure was obtained by having the feed pump controlled by the mercury level in the reservoir F. This reservoir was a manometer of large capacity, one leg of which was connected to a large tank of gas and the other leg served as the hydrocarbon reservoir. When the pump was in operation it forced the mercury down on the right-hand side until contact H touched the mercury, which by means of a relay stopped the pump. As the hydrocarbon flowed out, the gas storage forced the mercury up to contact K, which restarted the pump and the cycle. The ballast tank L was maintained approximately at the desired operating pressure, but owing to the variation of the mercury level in F,

slight pressure fluctuations would have developed if this pressure were maintained constant. In order to avoid this variation in pressure, gas was either bled in from the higher-pressure cylinder *M* or released through the waste-gas line. This fine adjustment of the pressure was manual and was controlled so that the piston of the dead-weight gauge floated freely at all times.

The electrical input was measured by calibrated voltmeter and ammeter, and the rate of flow was determined by weighing the condensate from *U* over a given period of time. The dead-weight gauge was calibrated against the vapor pressure of carbon dioxide as described by Bridgeman.[8] Temperatures were measured with calibrated chromel-P-alumel thermocouples to an accuracy of ±0.1° C.

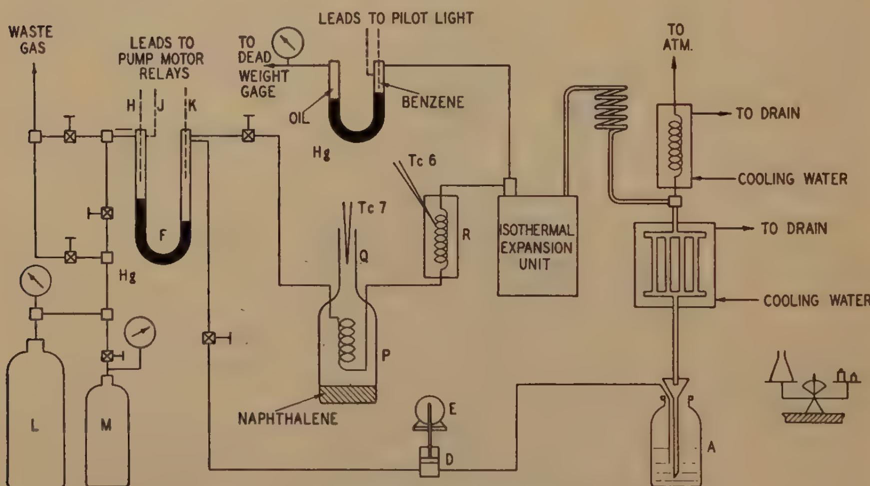

Fig. 11.—Flowsheet of expansion apparatus.

Results on Benzene

The effect of pressure on the enthalpy of benzene was determined with this apparatus. The benzene used was Baker's chemically pure and the results of this work are summarized in Table 2 and plotted in Fig. 12. The values of the change in enthalpy between various pressures and zero pressure divided by the absolute temperature are given in Table 2 as a function of the reduced temperature (absolute temperature divided by the critical temperature) and the reduced pressure (pressure divided by the critical pressure). These values have been corrected from atmospheric pressure to zero pressure by the use of Young's pressure-volume-temperature data on benzene. This correction was less than 1 per cent of the measured $(H_0 - H_p)/T$ values in all but a few cases. Fig. 12 gives a plot of the uncorrected experimental results, with the envelope curve for

saturated vapor and liquid being fitted in by the use of Young's vapor-pressure data for benzene.

These data on benzene cannot be compared directly with values calculated from pressure-volume-temperature data, because of the lack of sufficient measurements of the latter type. However, when the calculations based on pressure-volume-temperature data available for other hydrocarbons are plotted in this same manner, the difference between the plots for the various substances is not very great. These values of

TABLE 2.—*Results on Benzene*

Values of $\frac{H_0 - H_p}{T}$, B.t.u. per Lb. Moles per Deg. R.

P_R	$T_R = 0.70$	$T_R = 0.80$	$T_R = 0.90$	$T_R = 1.0$	$T_R = 1.10$	$T_R = 1.20$
4.0	17.1	14.1	11.5	9.27	7.31	5.52
3.0	17.7	14.3	11.7	9.29	7.05	4.75
2.0	17.8	14.4	11.7	9.14	6.19	3.62
1.6	17.8	14.4	11.7	8.98		
1.5	17.8	14.4	11.7		4.24	2.65
1.4	17.8	14.4	11.7	8.82		
1.2	17.9	14.5	11.6	8.51		
1.1	17.9	14.5	11.6	8.18		
1.0	17.9	14.5	11.6	6.05	2.39	1.54
0.9	17.9	14.5	11.6	3.48		
0.8	18.0	14.5	11.5	2.82	1.75	1.12
0.5	18.0	14.5	11.5	1.50	0.96	0.61
0.478			11.5[a]			
0.478			2.6[b]			
0.4	18.1	14.6	1.9		0.72	0.46
0.25	18.1	14.6	1.1	0.65	0.42	0.26
0.20	18.1	14.6	0.78			0.20
0.193		14.6[a]				
0.193		1.6[b]				
0.10	18.2	0.63	0.36	0.24	0.16	
0.0613	18.3[a]					
0.0613	1.1[b]					

$P_R = P/P_c$ and $T_R = T/T_c$; for benzene P_c = 47.89 atmospheres, T_c = 561.7° K.
[a] Saturated liquid. [b] Saturated vapor.

$(H_0 - H_p)/T$ for propane calculated from the data of Beattie, Kay, and Kaminsky[9] are only about 10 per cent less at the same reduced temperature and pressure than the corresponding values for *n*-heptane calculated from the data of Beattie and Kay, and the values for *n*-butane and isopentane fall between the propane and heptane values. Since this variation was small, the experimental results on benzene have been plotted in Fig. 13 together with the calculated *n*-heptane lines. The agreement is good except at the low of T_R, and the pressure-volume-temperature calculations are questionable in this region since extrapolations had to

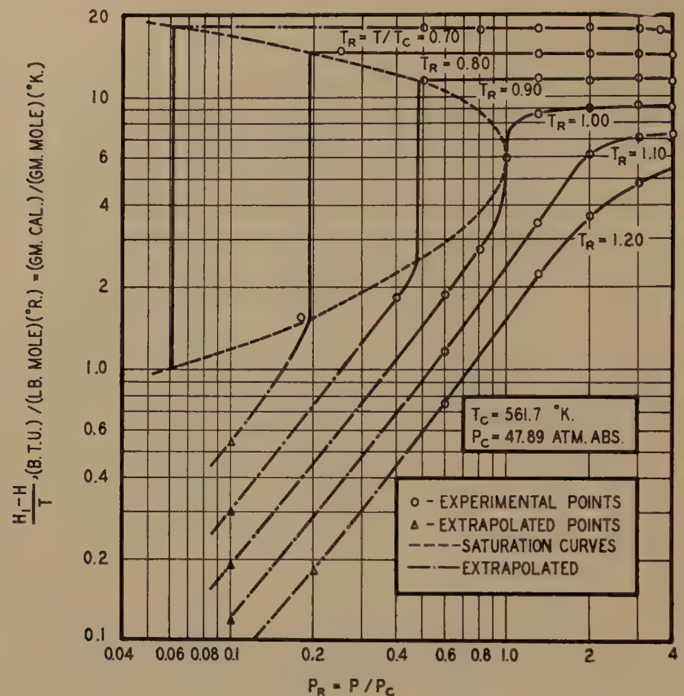

FIG. 12.—ENTHALPY OF BENZENE.

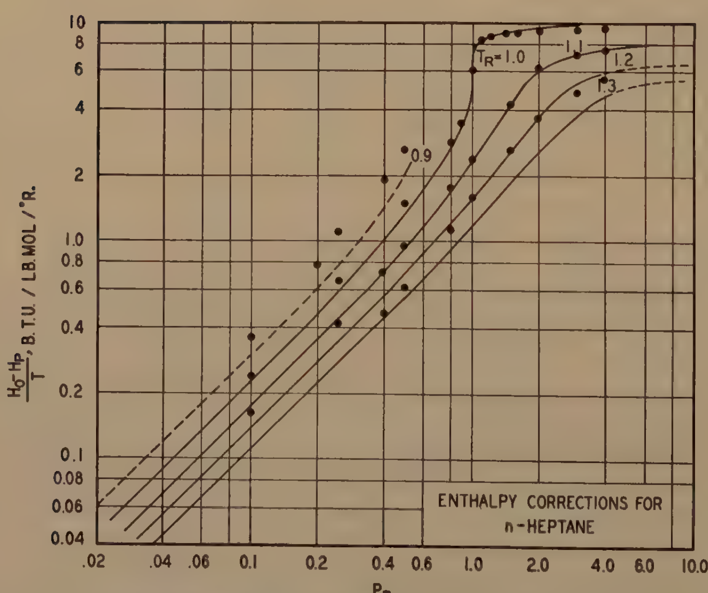

FIG. 13.—ENTHALPY CORRECTIONS FOR n-HEPTANE.

be used. The fact that the data for benzene and n-heptane agree so satisfactorily indicates that the enthalpy changes when correlated on the basis used in this figure are not greatly affected by organic series to which the hydrocarbon belongs.

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DISCUSSION

(*C. E. Reistle, Jr., presiding*)

R. C. Gunness* and W. C. Edmister,* Whiting, Ind. (written discussion).—The data presented in this paper should be valuable. The experimental techniques employed are undoubtedly sound.

A number of methods are available for the determination of the isothermal pressure

Table 3.—*Methods of Determining Correction*

P_r	$T_r = 0.90$			$T_r = 1.0$			$T_r = 1.10$			$T_r = 1.20$	
	L. and B.	G., L. and S.	E.	L. and B.	G., L. and S.	E.	L. and B.	G., L. and S.	E.	G., L. and S.	E.
0.1	4.20	4.24	4.20	3.73	3.14	3.03	3.6	2.3	2.5		
0.2	9.5	9.2	8.9							3.14	4.2
0.4	21.9	22.4	20.7				12.3	10.4	10.4		
0.5				19.6	19.6	17.4	15.2	13.8	13.2	9.6	10.8
0.8				33.8	37.0	34.2	25.8	25.2	22.6	17.6	17.8
0.9				40.9	45.6	45.3					
1.0				48.7	79.2	74.8	34.2	34.3	30.2	24.2	22.9
1.2					111.3	109.5					
2.0					120.0	118.5		89.0	78.3	56.8	52.2
3.0					121.5	121.6		101.0	91.0	74.6	72.0
4.0								105.0	95.4	86.7	79.0

* Research Department, Standard Oil Company (Indiana).

correction to the enthalpy of benzene. Data presented in this paper give the results of a direct determination by a constant-temperature experimental technique. Lindsay and Brown[11] have made similar determinations using the Joule-Thomson expansion experiment. Edmister[12] has computed the enthalpy correction from a generalized correlation of thermodynamic properties of hydrocarbons. Table 3 gives a comparison of the different methods of determining the correction. The correction H is expressed in British thermal units per pound to be subtracted from enthalpy at zero pressure. This comparison shows a maximum deviation of 10 B.t.u. per pound between Edmister's calculated and the authors' experimental data. Lindsay and Brown's data are in good agreement with the authors' except near the critical point.

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[11] Lindsay and Brown: *Ind. and Eng. Chem.* (1935) **27,** 817.
[12] Edmister: *Ind. and Eng. Chem.* (1938) **30,** 352.

Flow of Oil-water Mixtures through Unconsolidated Sands

By M. C. Leverett*

(San Antonio Meeting, October, 1938)

The behavior of mixtures of immiscible liquids in porous solids is of rapidly increasing interest to those engaged in the production of petroleum. The operation of artificial water-floods and the control of natural ones immediately raise questions concerning the fundamental nature of such processes. Moreover, it is now recognized that often water occurs dispersed throughout the rock from which the oil issues into the well,[1] and thus tends to move toward the well simultaneously with the oil. The work reported here is a laboratory investigation of the simultaneous, steady-state flow of oil and water through the same column of unconsolidated sand. It is thus directly related to the situation in which water occurs in oil-producing sands; it may have less direct implications for the displacement of oil from sands by water. However, it is to be clearly understood that the experiments to be described were performed primarily to obtain information of a more or less fundamental nature, and are not an attempt to reproduce, on laboratory scale, any part of an oil field.

The dynamic behavior of a system in which oil and water are flowing simultaneously through sand is best described in terms of its "effective permeability" to either phase. For incompressible fluids flowing through a system of uniform cross section, the effective permeabilities to the two phases, in darcys, may be defined by the equations:

$$K_0 = \frac{Q_0 \mu_0 N}{P \Delta \theta A} \qquad [1a]$$

and

$$K_w = \frac{Q_w \mu_w N}{P \Delta \theta A} \qquad [1b]$$

In order to put the results obtained on a comparable basis for different sands, the effective permeabilities will be stated as fractions of the normal permeability of the sand; i.e., fractions of its permeability to a homogeneous fluid. Algebraically, these fractions are:

$$K_0' = K_0/K, \qquad \text{and} \qquad K_w' = K_w/K \qquad [2a] \text{ and } [2b]$$

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[1] Production Research Dept., Humble Oil and Refining Co., Houston, Texas.

[1] References are at the end of the paper.

A preliminary analysis of the problem indicates that the following variables will be significant in determining the respective effective permeabilities: porosity and permeability of the sand (and possibly other quantities necessary adequately to describe the pore size distribution in the sand); viscosity and density of both liquid phases; the interfacial tension between the two liquids and their angle of contact on the sand surface; and finally, the pressure gradient under which flow occurs. The problem, then, is to determine experimentally what may be the effect of variations in these factors, and if possible to correlate the results so obtained into general statements.

Nomenclature

A, cross-sectional area of sand column, sq. cm.
a, difference between observed relative permeability to water and permeability that would be read from the line $K_w' = S$.
b, difference between observed relative permeability to oil and permeability that would be read from the line $K_0' = 1 - S$.
C', fraction of normal electrical conductivity, $C' = R_0/R$.
D, average pore diameter, cm.
K, homogeneous fluid permeability of sand, darcys.
K_0, K_w, permeability, darcys, to oil or water, respectively.
K_0', K_w', relative permeability to oil or water. $K_0' = K_0/K$. $K_w' = K_w/K$.
K' indicates relative permeability to either phase, not specified.
M, viscosity ratio, μ_0/μ_w.
N, length of sand column under test, cm.
P, pressure differential, cm. mercury (except in equations 1*a* and 1*b*, when P is in atmospheres).
R_0, electrical impedance of sand section with all pore space filled with water.
R, electrical impedance of same sand section with fraction S of pore space filled with water, remainder oil.
S, water saturation, fraction of pore space filled with water.
Q_0, Q_w, volume of oil or water passed in $\Delta\theta$ sec.
X, fraction of effluent from sand that is water.
α, angle of contact.
γ, interfacial tension, dynes per cm.
$\Delta\theta$, time interval, sec.
μ_0, μ_w, viscosity of oil or water, centipoises.
π, displacement pressure, cm. mercury.
ϕ, porosity, fraction.

Previous Work

Wyckoff and Botset[2] have investigated a system somewhat similar to that used in the present work. These authors reported the results of experiments in which gas-liquid mixtures were passed through unconsolidated sands of from 11 to 260 darcys permeability. Additional experiments were performed in which oil-water mixtures were similarly treated, and it was concluded that the flow mechanism was essentially similar for the two systems. Moderate variations in the viscosities of the fluid phases failed to affect the relative permeability values. Experi-

ments on a wide variety of sands failed to show any marked influence of sand structure on permeability, as did also tenfold variations in flow rates and twofold variations in surface tension. It thus appeared to these investigators that the effective permeability was a unique function of the existing water (liquid) saturation, although it was intimated that under suitable conditions other variables might become significant.

Reid and Huntington[3] have since verified a part of this excellent investigation, and Plummer, Hunter, and Timmerman[4] have contributed data on two-phase flow through sands under different experimental conditions. Information concerning the displacement of one fluid from a sand by another has been reported by Dunlap,[5] Hassler, Rice and Leeman,[6] Lindtrop and Nikolaeff,[7] and others.

Experimental Methods

The technique employed in the present investigation was closely similar to that developed by Wyckoff and Botset. The procedure com-

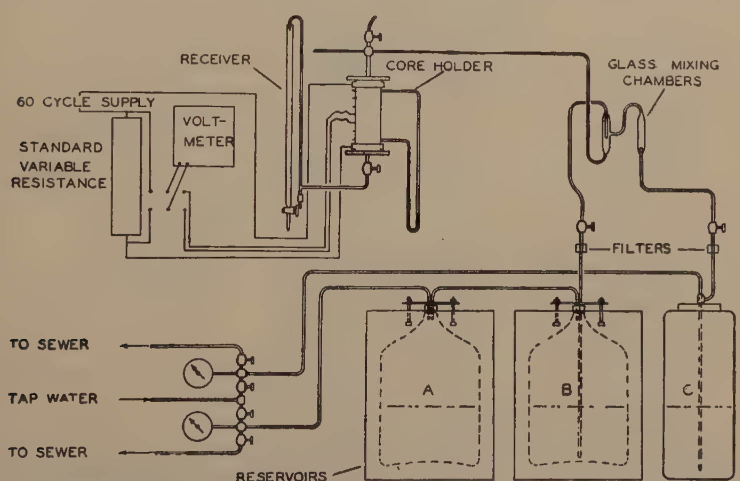


FIG. 1.—ARRANGEMENT OF APPARATUS FOR STUDYING FLOW OF OIL-WATER MIXTURES THROUGH UNCONSOLIDATED SANDS.

prised introduction, at a steady rate, of a mixture of oil and water into a vertical column of unconsolidated sand. Relative permeabilities and water saturations were observed after steady conditions had been attained.

The arrangement of the apparatus is shown in Fig. 1. Fig. 2 shows some details of the core holder used for confining the sand. By means of the manometer (Fig. 1) the pressure differential across a central section of the core could be determined, and this, coupled with measurements of the efflux rates of both liquids, viscosities of both liquids and dimensions of the apparatus, sufficed for computation of the effective permeability of the sand column under the test conditions.

The water saturation of the core was determined from its electrical conductivity. For this purpose, a small 60-cycle current was passed through the column in the direction of its long axis. Seven potential-measuring electrodes (split brass rings, recessed flush into the nonconducting walls) divided the portion of the column under observation into

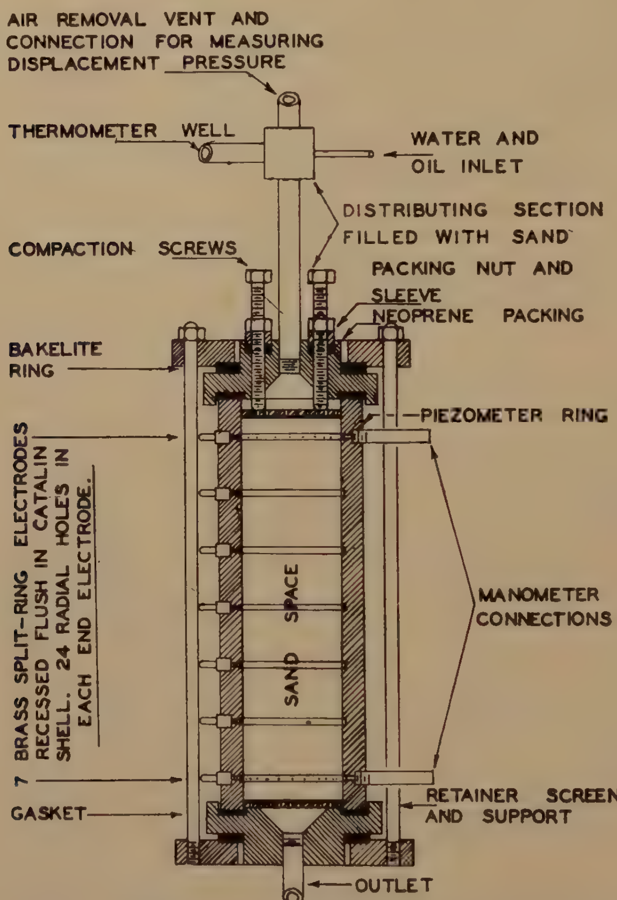


FIG. 2.—SECTION SHOWING DETAILS OF CORE HOLDER.

six sections, across each of which the potential drop could be measured. The end electrodes were perforated radially, the holes communicating, through an annular space back of the electrode, with the manometer connections.

In order to avoid inclusion of potential drops due to contact impedances, the current was introduced at the stainless-steel perforated plates supporting the retainer screens, rather than at the electrodes used for

measuring the potential drops. In series with the sand column was connected a variable known resistance. In operation, the value of this resistance was adjusted until the potential drop across it was the same as that between adjacent potential-measuring electrodes on the core holder. The value of the known resistance was then directly the impedance of the section of the core being examined. A vacuum-tube voltmeter was used for making the necessary comparisons of potential drops. The division of the sand column into six sections permitted the checking of the uniformity of water distribution in it. The end sections of the column were not included in the tests because some of the preliminary work

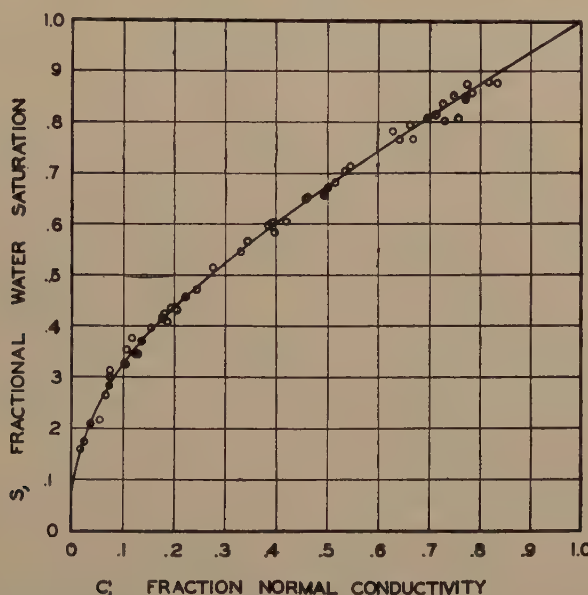


FIG. 3.—CALIBRATION CURVE, ELECTRICAL CONDUCTIVITY-WATER SATURATION.

indicated that the discontinuities at the ends of the column introduced disturbing influences.

It was necessary, of course, to know the manner in which the impedance varied with water content. This was determined in an apparatus small enough to be weighed on the analytical balance, the water saturation being determined from the density difference between the oil and water and appropriate weighings. The results were expressed as the "fraction of normal conductivity" which the sand-water-oil complex exhibited, in the manner of Wyckoff and Botset. Several conductivity-saturation observations were made on each system used, and it was found that all the observations fell satisfactorily near the same curve (Fig. 3). This curve deviates only slightly from that of Wyckoff and Botset. In

order to make the water slightly conducting, it was usually made about 7N in sodium chloride.

The apparatus for supplying the oil-water mixture to the core is also indicated in Fig. 1. Reservoir *A* contained an oil (kerosene), which, when tap water was injected into reservoir *A*, displaced the conducting water out of reservoir B. The conducting water then entered the observation chamber dropwise, emerging in a glass chamber filled with the oil under test. This oil, in turn, came from reservoir *C*, from which it was displaced by tap water. It too entered the glass observation chamber dropwise, emerging in water previously placed in the right-hand bulb. The mixture left the observation chamber through a capillary-bore tube, which discharged it into the distributing section ahead of the sand column. This section, filled with sand, served to smooth out irregularities due to the dropwise admission of the liquids. The tap water used to displace the liquids from the reservoirs was admitted through a throttling arrangement, for convenience in controlling its pressure.

The procedure used was as follows: Dry sand, previously washed free of clayey constituents, and ignited (1000° C.) and screened to size, was weighed into the core holder. The latter was then closed and evacuated, and previously deaerated distilled water permitted to enter it from the bottom. The conducting water (also previously deaerated) was then passed downward through the sand under two or three atmospheres back pressure until it was certain that any residual traces of air had been dissolved, and all the distilled water displaced. The electrical impedance of each section was then determined, and the permeability to conducting water measured.

At this point the displacement pressure[8] (pressure just insufficient to force oil into the completely water-saturated sand column) was determined as follows: A tall glass tube was attached vertically to the top of the apparatus (Fig. 2). The oil to be used was placed in this tube and, with the bottom outlet valve open, allowed to penetrate under its own head into the core as far as it would go, forcing water out of the glass delivery tube. The pressure corresponding to the difference in hydrostatic heads when the oil level ceased to fall was then computed from the liquid densities, and reported as the displacement pressure. Several hours were usually allowed for equilibrium to be attained.

After measurement of the displacement pressure, the distributing section was filled with sand. Oil-water mixtures of constant composition were then introduced at various steady rates, the pressure differential, efflux rates, temperature and resistances corresponding to each steady state being noted after equilibrium had been attained. Since running a complete series of observations on a given system required from two to six weeks, two complete sets of apparatus were constructed and operated simultaneously.

Results

In so far as possible, the experiments were chosen to show the effects of variation in a single property of the system, therefore the results will be presented in this manner, although there is, obviously, considerable unavoidable overlapping.

Effect of Variations in Liquid Viscosities

The effects of variations in liquid viscosities were explored in four runs. In these experiments sand of the same screen analysis (100 per cent 100 to 200 mesh) was used throughout, although, owing to differences in packing and in size distribution between the two extremes, it exhibited different permeabilities and porosities. Table 1 summarizes the properties of the four systems.

TABLE 1.—*Properties of the Four Systems*

Properties	System			
	1	2	3	4
Sand permeability, darcys	5.1	6.8	3.2	4.2
Sand porosity, fraction	0.41	0.42	0.40	0.41
Oil viscosity, centipoises	76.5	1.55	0.31	1.63
Water viscosity, centipoises	0.85	0.86	0.89	32.2
Viscosity ratio, $M(\mu_0/\mu_w)$	90.0	1.80	0.35	0.057
Interfacial tension, dynes per cm	24.	34.	31.	26.
Displacement pressure, cm. Hg	2.3	2.2		2.8
Specific gravity of oil	0.87	0.80	0.66	0.80
Specific gravity of water	1.00	1.00	1.00	1.22

The oils used were hydrocarbon products, a close-cut hexane fraction being the least viscous and a commercial lubricating oil most viscous, while kerosene was used for the oil of intermediate viscosity. In one run the viscosity of the water was increased by the addition of U.S.P. glycerol. Eliminating, for reasons to be explained subsequently, data taken at very low pressure gradients, the results were plotted as K' vs. S (Figs. 4 and 5). Although there are relatively small deviations of the data from an average curve, there are no systematic deviations of the order of magnitude of the viscosity differences. It is concluded therefore that the relative permeability is substantially independent of the viscosity of either phase. It likewise appears that relatively *small* variations in interfacial tension, porosity, permeability and liquid density differences exert insignificant influences on the relative permeability at a particular value of S.

The lack of influence of liquid viscosity on relative permeability has several significant consequences. First, it throws light on the mechanism

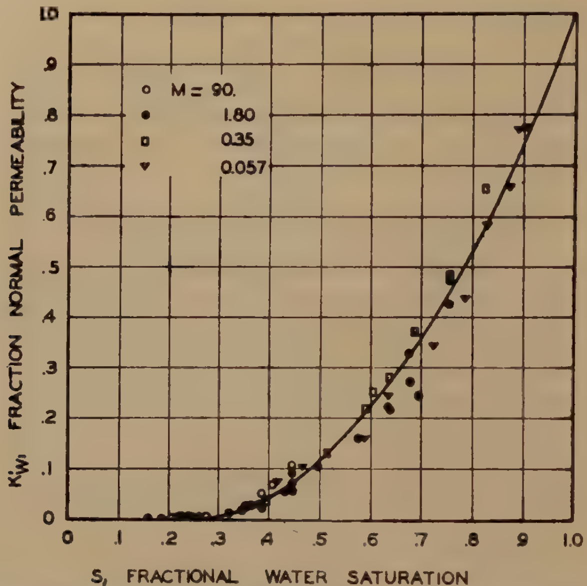


FIG. 4.—EFFECT OF VISCOSITY RATIO M ON K_w' VS. S CURVE FOR 100 TO 200-MESH SAND.

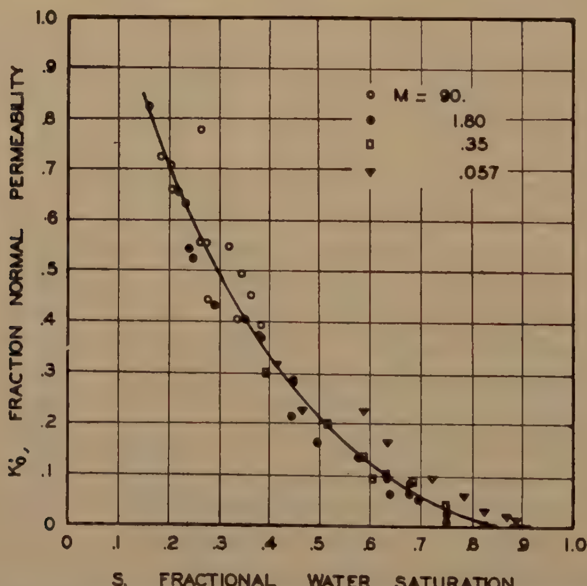


FIG. 5.—EFFECT OF VISCOSITY RATIO M ON K_0' VS. S CURVE FOR 100 TO 200-MESH SAND.

of flow, since it will be noted that the observed behavior is the same as though, at a given value of S, the system were composed of a bundle of parallel, noninterconnecting capillary tubes, each of which was filled with water alone or oil alone, although such "pipelike" flow probably does not completely represent actual conditions in the sand. Other mechanisms have been considered, but except at low oil saturations it appears likely that most of the oil moved through the larger channels, which contained very little water. The water, in all probability, flowed through channels too small for penetration by the oil and as a continuous sheath around each sand grain. The presence of a continuous

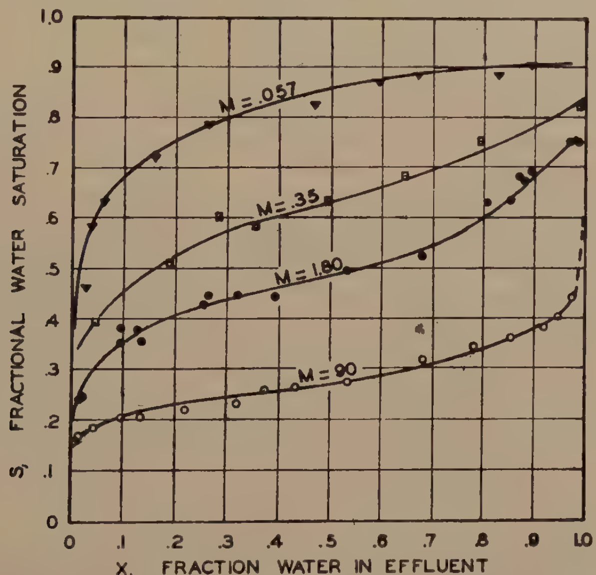


FIG. 6.—EFFECT OF VISCOSITY RATIO M ON WATER SATURATION CORRESPONDING TO PASSAGE OF AN OIL-WATER MIXTURE OF DEFINITE COMPOSITION.

water sheath is postulated on the assumption that the contact angle was zero. While this is believed to have been the case in the experimental work, it is not necessarily true of actual oil sands. Finally, in order to account for the fact that the sum $(K_0' + K_w')$ deviates from unity, it may be supposed that scattered throughout the sand are droplets of oil locked in small cul-de-sacs formed by the configuration of the sand pores (i.e., the Jamin effect). This oil not only does not flow, but obstructs the flow of water.

A second consequence becomes apparent on replotting the data to show S, the water saturation resulting when a mixture, of which a fraction X is water, is passed through the sand column. This has been done in Fig. 6 for the four runs summarized in Table 1. Under the experimental conditions, the viscosity ratio M influences to a marked degree the com-

position of the mixture issuing from a sand containing a given fraction of its pore space filled with water. In this connection it is important to recall that these data were taken at pressure gradients that were relatively high. Indeed, it is likely that in an actual oil field pressure gradients of this magnitude occur only very near wells. It will be shown later that the S-X relation (Fig. 6) is strongly influenced by changes in P/N, the pressure gradient.

The curves of Fig. 6 are flat over much of their length; there is thus indicated a comparatively narrow range of water saturations at which mixtures containing substantial proportions of both liquids will be produced. When the oil viscosity is low this range of water saturations lies fairly high on the water-saturation coordinate. Since the oil saturation at this point is correspondingly low, the amount of oil that may possibly be recovered after the sand commences to make substantial quantities of water is also small. In contrast, when the viscosity of the oil is high, the range of water saturations at which mixtures containing substantial proportions of both liquids will be produced lies fairly low on the water-saturation coordinate. It is inferred from this fact that the amount of oil that may possibly be recovered is large. However, in this second condition large amounts of water will accompany the oil, and recovery of such an oil will necessarily be more costly than recovery of an equal amount of a less viscous oil.

A further consequence of the appearance of the curves of Fig. 6 is that low oil viscosity will, in general, correspond to a relatively low fraction of water in the production from a sand. There is, then, an evident advantage to be gained by maintaining as much as possible of the original gas in solution in the oil, since its loss increases the oil viscosity.

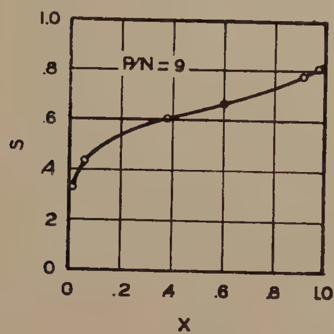
Although Fig. 6 shows actual data points, it is to be remarked that the curves of Fig. 6 may be computed from those of Figs. 4 and 5 together, since, at any particular value of S

$$X = \frac{1}{\dfrac{K_0'\mu_w}{K_w'\mu_0} + 1} \qquad [3]$$

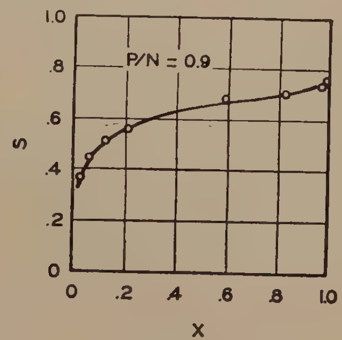
Wyckoff and Botset likewise concluded from their experiments that the relative permeability was independent of viscosity. Their data are, over much of the saturation range, displaced relatively to the right of the curves of Figs. 4 and 5. This is believed to be associated with a fundamental difference between the two cases, in that in the present work oil may enter pores no smaller than the critical size determined by the pressure gradient and interfacial tension; in gas-liquid flow, however, gas may be released from solution at any point within the liquid at which the absolute pressure drops below the saturation pressure of the solution. Gas may thus exist, momentarily, in any pore, however small.

Effect of Variations in Pressure Gradient

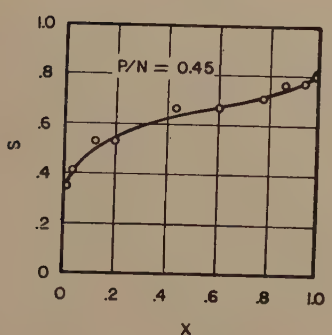
Early in the experimental work, it was discovered that in general the permeabilities observed were lower when measured at low pressure differ-



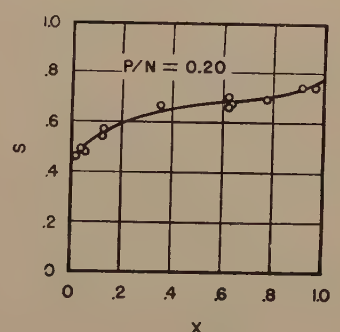
a. $P/N = 9$.



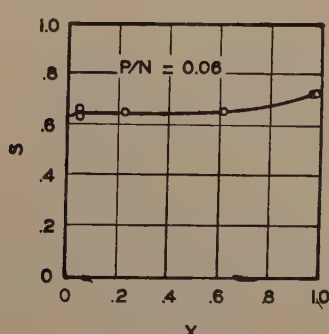
b. $P/N = 0.9$.



c. $P/N = 0.45$.



d. $P/N = 0.20$.



e. $P/N = 0.06$.

FIG. 7.—S VS. X RELATION FOR SAND OF 1.04 DARCYS PERMEABILITY.

entials than at high ones. This result is completely understandable in view of the nature of the Jamin effect, which presumably accounts for most of the deviation of the sum $(K_0' + K_w')$ from unity. However, it

was found that the effective permeabilities observed at very low (less than about 0.1 to 0.2 cm. mercury per cm.) pressure gradients were highly erratic, this characteristic becoming more pronounced as the pressure gradient was further decreased. This effect, while possibly due in some degree to the lack of inherent reproducibility of conditions in the system, was probably due principally to unavoidable inaccuracies in measuring the pressure differentials. The inaccuracies are thought to arise from the fact that the pressure differentials being measured were of the same order of magnitude as the pressures set up by capillarity at the boundaries of the sand mass. The observed pressure differential therefore might be in error by the amount of these unknown capillary pressures.

However, the degree of reproducibility obtainable on plots of S vs. X is affected to a much smaller degree by low pressure gradients. Fig. 7 shows the influence of P/N on the S vs. X curves for a sand of 1.04 darcy permeability. M was about 0.35. The value of P/N shown on each plot is the average value for the several points appearing on that plot.

While the curves change their shapes only slightly at the higher pressure gradients used, reduction of P/N to 0.2 produces an unmistakable flattening of the curve, while at $P/N = 0.06$, S is almost independent of X over a large part of the range. This is a fact of possible practical importance, since it indicates that the composition of the mixture produced from a sand containing both oil and water is importantly influenced by the pressure gradient (and hence the rate) at which production occurs. Under the experimental conditions, it appears that where the water saturation is less than about 65 per cent it will be advantageous to produce at slow rates, since the liquid recovered will then be almost entirely oil until a saturation of about 65 per cent water is reached. Above 65 per cent water saturation, some reduction in percentage of water produced should attend an increase in the flow rate, but inasmuch as the percentage of water in the stream will always be high, this will yield a somewhat smaller advantage than slow production below 65 per cent water saturation. Furthermore, it is extremely unlikely that pressure gradients approaching $P/N = 0.5$ will ever be attained over any considerable part of an oil field.

The discussion of the data presented here in terms of field-scale practice is merely for the purpose of clarifying their general meaning, and their direct application to any particular case must be made cautiously and with full knowledge of the prevailing conditions.

The tendency of the S-X curves to become straight, horizontal lines indicates the progressive narrowing of the range of water saturations at which both oil and water are produced in substantial quantities from the same sand as the pressure gradient is reduced. It is indicated too that at low pressure gradients once water appears in the production from such a sand it will rapidly become a large part of the mixture produced.

Effect of Variations in Interfacial Properties

The interfacial properties of the oil-water-sand complex may be expressed in terms of the oil-water interfacial tension, and the contact angle of the two liquids on the solid. The latter factor is not susceptible of direct measurement on irregular surfaces, but Bartell[8] has discovered that its cosine bears a linear, but empirical, relation to the displacement pressure.

The displacement pressure in relatively coarse solids, such as sands, may be supposed still to be linear in γ, the interfacial tension and the cosine of the contact angle α. However, Bartell reports that his empirical proportionality constant is no longer valid when the particle size of the solid exceeds certain limits, or if the degree of compaction to which the powdered solid is subjected is insufficient. It thus appears that the displacement pressure in such coarse sands as those in which oil usually occurs does not have the quantitative significance it appears to have under the special conditions indicated previously. The displacement pressure does, however, embody directly two factors difficult to determine separately; namely, the contact angle and the effective geometry of a particular element of the sand. These facts alone would justify use of π, the displacement pressure, as a measure of the strength of capillary forces within a particular sand. However, the most cogent argument is the very obvious one that it is, directly, the minimum pressure differential that suffices to force oil through the sand through the least resistant channel, and is thus closely related to the Jamin effect in this channel. The pressure differential required for other channels may be supposed to be related to this minimum value. Hence the displacement pressure is to be regarded as an index of the magnitude of interfacial forces in the present experiments.

It was believed that the sand surface in the present work was entirely covered with a water film, due to the generally hydrophilic nature of silica surfaces and the method of preparation of the sand. The presence of such a film is indicated too from the similarity of the S-C' curve (Fig. 3) to the corresponding curve for gas-liquid mixtures reported by Wyckoff and Botset. It is almost certain that for the gas-liquid mixtures α was zero. Variations in π, in this work are, then, probably due to variations in γ, the interfacial tension and in the pore size of the sands used.

In order to effect a large variation in π, it was desired to reduce γ to a fairly low value. The first attempt to do this comprised the addition to the conducting water of a reducer of interfacial tension of the sodium alkyl sulphate type. The result was the formation of practically rigid kerosene-water emulsions within the sand, thus verifying the experience of Wyckoff and Botset. However, on substituting for the kerosene a pure organic liquid of which the interfacial tension against water was low (amyl

alcohol), the trouble disappeared and a series of observations was made in the usual manner. γ was about 5 dynes per cm. and π about 0.24 cm. mercury. The sand used was 100 per cent 100 to 200 mesh, hence the results are comparable with those of Figs. 4 and 5. They are plotted in Fig. 8, with the average curves from Figs. 4 and 5 presented for comparison. There is evidently a small but definite tendency for the system to exhibit higher relative permeabilities as π is decreased by decreasing γ. This effect is in opposite direction to the one caused by a decrease in the

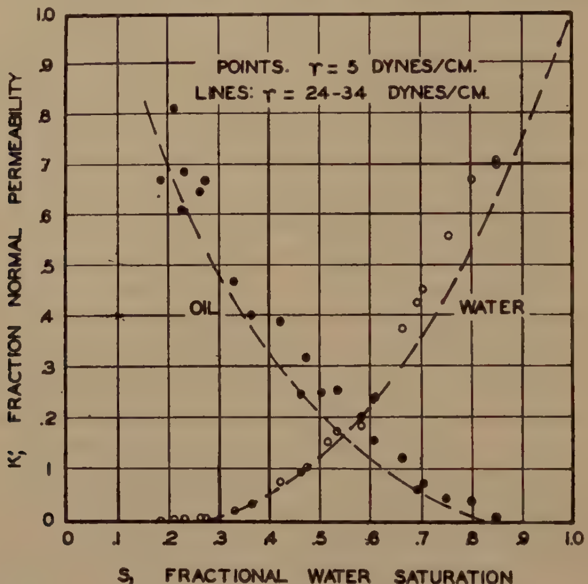


FIG. 8.—COMPARISON OF K' VS. S RELATIONS FOR TWO LIQUID PAIRS OF WIDELY DIFFERENT INTERFACIAL TENSIONS.

applied pressure differential, and is, again, what would be predicted from the general nature of the Jamin effect.

Effects of Variations in Sand Structure

Exploration of this phase of the problem has been limited to sands of three different size assortments (Tables 2 and 3). Sand I will be recognized as the one used in the experiments summarized in Table 1. Table 3 also summarizes the conditions under which observations were made on sands II and III.

The experiments on sands II and III were conducted at several pressure gradients. The data obtained at approximately the same pressure gradients as the average of the data plotted in Figs. 4 and 5 are plotted in Fig. 9. Despite the rather erratic appearance of the data for sand II, it is concluded that it shows characteristics decidedly different from those of sands I and III, which appear (probably fortuitously) to be very similar.

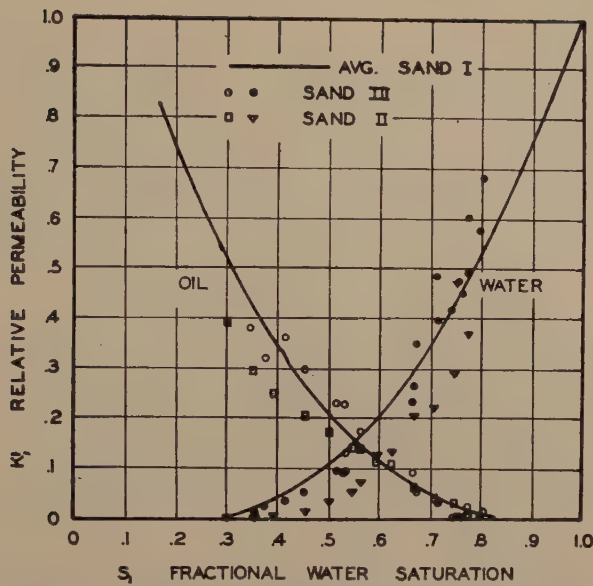


FIG. 9.—COMPARISON OF PERMEABILITY-SATURATION RELATIONS FOR THREE DIFFERENT SANDS.

TABLE 2.—*Sizes of Sands*

Sand	Screen Analysis, Per Cent		
	100 to 200 Mesh	200 to 325 Mesh	Through 325 Mesh
I	100	0	0
II	50	25	25
III	25	25	50

TABLE 3.—*Properties of Sands*

Properties	Sand II	Sand III
Permeability, darcys	1.75	1.04
Porosity, fraction	0.35	0.45
Oil viscosity, centipoises	1.63	0.30
Water viscosity, centipoises	0.91	0.88
Viscosity ratio, M	1.79	0.34
Interfacial tension, dynes per cm	30.	34.
Displacement pressure, cm. mercury	4.6	3.0
Specific gravity of oil	0.81	0.66
Specific gravity of water	1.01	1.01

Unfortunately, an insufficient number of sands have so far been investigated to permit generalization of the permeability-saturation relation in terms of properties of the sand. One may suppose that this relation is closely associated with the pore-size distribution, for which a quantitative expression is not to be obtained from the usual measurements of macrcscopic porosity and permeability. For the present it can only be said that considerable differences in behavior between different sands have been observed.

Effect of Variations in Liquid Densities

The fact that, in the experiments described, the liquids were passed vertically downward through the sand (it was feared that horizontal flow would give rise to stratification within the core) raises the question of whether the observed permeabilities are not too high for the denser phase and too low for the lighter one. Experiments performed to clarify this point indicated that errors due to this cause were present, but that they were not significantly large.

Correlation of Results

It has already been pointed out that insufficient data are as yet available to show the manner in which the permeability-saturation relation varies with changes in the characteristics of the sands used. However, considerable information has been obtained on the variation of the K'-S relation with pressure gradient and interfacial tension. Attention will therefore be directed to correlating the effects of these two variables for the particular sands investigated, with the hope that when additional data are available the correlation may be generalized to include sands of various pore-size distributions.

Now, it appears likely that the major cause of the deviation of the sum $(K_0' + K_w')$ from unity is the presence in the sand of discrete globules of oil, which are lodged against openings too small to permit their passage under the existing pressure gradient (the Jamin effect). Supposing that the average length of the oil globules is proportional to D, the average pore diameter, the average pressure differential per globule is evidently proportional to PD/N. This pressure differential is opposed by capillary forces which are proportional to π, the displacement pressure, and if all the globules were equal and identically situated none would move until PD/N exceeded a certain critical value proportional to π. However, the globules are not all of the same size, nor are they identically situated, so that at a particular pressure gradient it may be supposed that a certain proportion of the globules have been forced through the apertures against which they were lodged. It will now be assumed that this proportion is a function only of the dimensionless group $\pi N/PD$. However, the relative permeability is also related to the proportion of the oil globules that have

been dislodged, and one may as well assume that the relative permeability, or some quantity related to it, is a function of $\pi N/PD$, but not necessarily a unique function, since it is already known that, at constant values of the variables appearing in the above group, K' is a function of the water saturation S.

In testing the data to see whether, in fact, they fit the assumption that K' is a function only of S and $\pi N/PD$, it will be convenient to have a reference permeability, deviations from which will be correlated, rather than the permeabilities themselves.

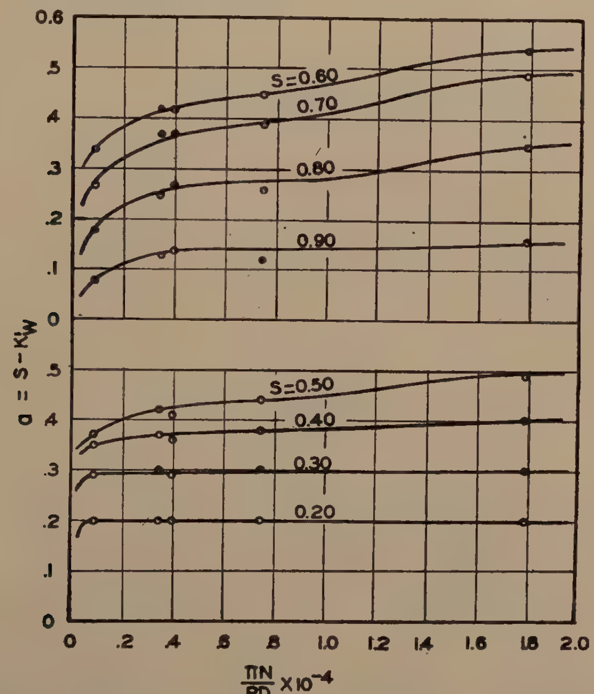


FIG. 10.—PLOTS SHOWING VARIATION OF a WITH $\pi N/PD$ AT VARIOUS VALUES OF S. DATA TAKEN ON SANDS I AND III.

It has been pointed out previously that the system behaves as though composed of a bundle of parallel, noninterconnected capillaries of various sizes. If such a hypothetical bundle were supplied randomly with oil and water so that there would be no segregation of either liquid in a particular size of tube, but so that any given tube contained only one or the other liquid, the permeability-saturation plots would be straight 45° lines passing through the corners of the diagram; i.e., simply the diagonals. In actual sands, however, because of interfacial forces, deviations from these lines occur, but it may be supposed that such deviations would disappear in a hypothetical sand-oil-water system in which the same tubelike flow prevailed but in which all interfacial forces

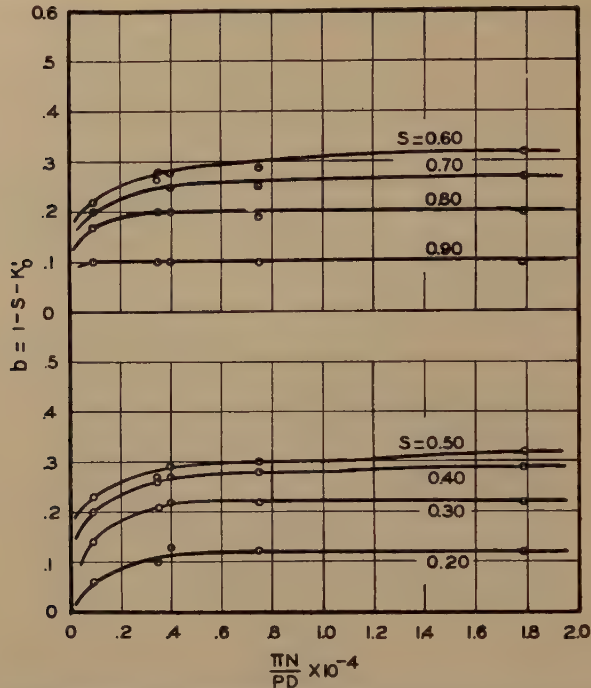


FIG. 11.—Plots showing variation of b with $\pi N/PD$ at various values of S. Data taken on sands I and III.

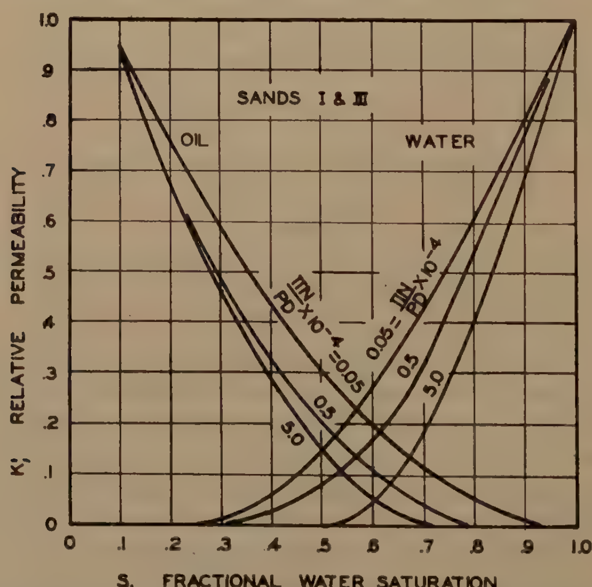


FIG. 12.—Relative permeability to oil and water as a function of water saturation with the group $\pi N/PD$ as a parameter. Calculated from figs. 11 and 12.

had been reduced to zero. Actually, reduction of the displacement pressure does decrease the deviation from the diagonals, and increasing the pressure gradient, which reduces the relative importance of interfacial forces, has the same effect. The diagonals, therefore, will be used for reference purposes, and the deviations from them will be used for correlation with $\pi N/PD$ and S. It will be noted that it is not assumed that these deviations will become indefinitely small as the value of π is indefinitely reduced, although the assumption that both will decrease may be used as an aid in extrapolation of the data.

The term D, appearing above, may not be evaluated directly, but it is customary to assign to it the numerical value of the diameter of each tube of a hypothetical bundle of circular, parallel, straight, identical capillaries which would, in bulk, have the same porosity and permeability as the sand under observation. Numerically, D, in centimeters, is:

$$D = 5.63 \times 10^{-4}\sqrt{K/\phi} \qquad [4]$$

The steps taken to determine whether K' varies systematically with $\pi N/PD$ at a given value of S were as follows:

1. A series of K'-S observations was made at a constant value of $\pi N/PD$; i.e., at constant pressure gradient for a particular system.

2. These were plotted to show the deviation (a for water and b for oil) of K' from the diagonals. Numerically,

$$a = S - K_w' \qquad \text{and} \qquad b = 1 - S - K_0' \qquad [5a] \text{ and } [5b]$$

3. Several such curves, obtained on sands I and III, were then cross-plotted to show a (or b) as a function of $\pi N/PD$ at constant values of S. The results of this operation appear in Figs. 10 and 11.

There is a smooth variation of a (and b) with $\pi N/PD$.

From the curves of Figs. 10 and 11 can be computed the effective permeabilities corresponding to any values of S and $\pi N/PD$. Fig. 12 shows the results of such a computation for sands I and III, the data for which were combined.

In order to show the extent to which this correlation describes the data, one may utilize the fact that plotting the data as $(K_w' + a)$ vs. S and $(K_0' + b)$ vs. S should give straight lines passing through the corners of the diagram. This has been done for sands I and III in Fig. 13, on which are shown not only the data from which the correlation curves were established but also an approximately equal number of data that were not used in establishing the correlation, since they were not part of a series of observations made at constant values of $\pi N/PD$. These data were taken on sands I and III, the liquid viscosities, density differences and pressure gradients covering a fairly wide range of values, with smaller variations in π. The data in Fig. 13 indicate that, while there are a number of fairly large individual deviations from the correla-

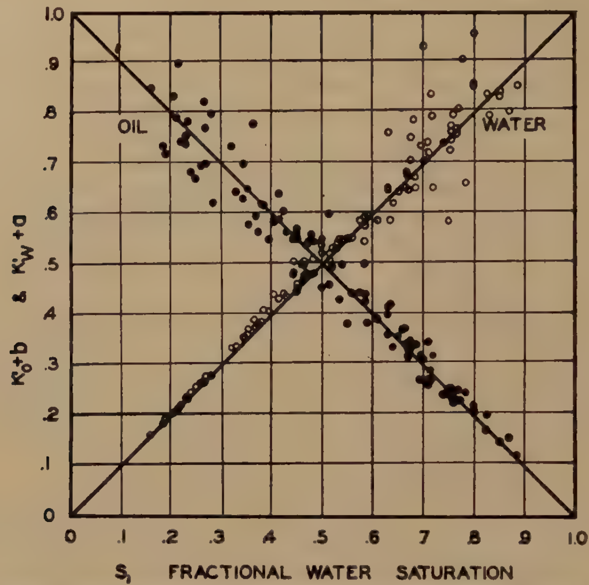


FIG. 13.—GENERAL AGREEMENT OF ALL DATA ON SANDS I AND III WHEN CALCULATED DEVIATIONS FROM DIAGONALS ARE ADDED TO OBSERVED RELATIVE PERMEABILITIES.

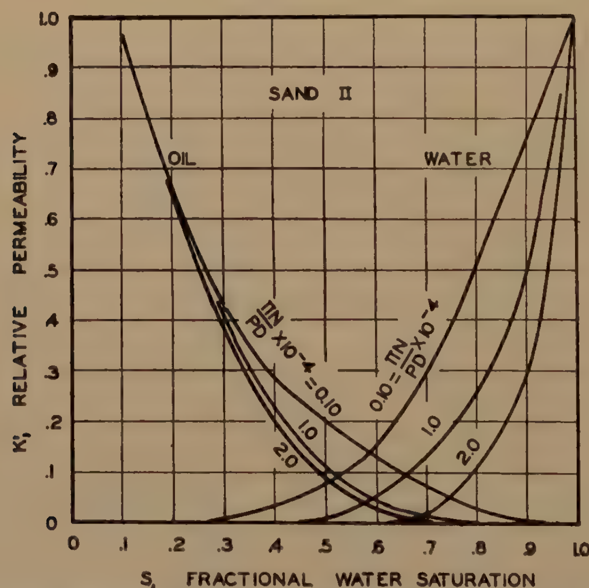


FIG. 14.—RELATIVE PERMEABILITY TO OIL AND WATER AS A FUNCTION OF WATER SATURATION WITH THE GROUP $\pi N/PD$ AS A PARAMETER. CALCULATED FROM PLOTS SIMILAR TO FIGS. 11 AND 12.

tion, the general agreement is satisfactory. Qualitatively similar results were obtained on the other sand investigated, and Fig. 14 shows curves corresponding to Fig. 12 for this sand.

Conclusions

From the results of the experimental work performed, it is concluded that the relative permeability of an unconsolidated sand to oil-water mixtures is substantially independent of the viscosity of either liquid, but is related to its pore size distribution, and to the displacement pressure, pressure gradient and water saturation that characterize the process. It is pointed out that the effects of these variables are in the direction to be predicted from a knowledge of the Jamin effect. It is concluded that the most probable mechanism of flow comprises segregation of most of the flowing oil in the larger channels between sand grains. Each such channel is believed to be substantially full of oil, except at very low oil saturations, when the oil probably moves as discrete droplets through the channels. In either case some oil is thought to be stationary within the sand. The water is believed to flow through the channels that are not occupied by oil, and, in the present case, as a continuous film around each sand grain.

It is proposed that, for a particular sand, the relative permeability to either phase is a function of the water saturation and the dimensionless group $\pi N/PD$ only, and it is shown that the data presented substantiate this view.

Acknowledgment

The author gratefully acknowledges the assistance and cooperation of the Humble Oil and Refining Co. in carrying out this research.

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DISCUSSION

(W. E. Winn presiding)

H. G. Botset,* Pittsburgh, Pa. (written discussion).—This paper presents an excellent and thorough study of the phenomena involved in the flow of oil-water

* Gulf Research and Development Co.

mixtures through unconsolidated sands. The use of the $\pi N/PD$ relationship in studying the deviations of the permeability-saturation curves from straight lines has proved to be very fruitful. It is gratifying to see conclusions derived at this laboratory, after comparatively meager experiments, as to the relative unimportance of interfacial tension, compressibility and viscosity on the permeability-saturation relation, so thoroughly confirmed by the present paper.

It is interesting that the curves of Fig. 7 never rise above 80 per cent water saturation, even when the effluent liquid is practically 100 per cent water. At the two lowest gradients the maximum water saturation is even slightly lower. This is what would be expected from the concept of equilibrium saturation; a minimum saturation in the dispersed phase (in this case, oil) is built up, even if only a trace of the dispersed phase is present. In gas-liquid mixtures this equilibrium saturation is maintained only for very low pressure gradients, but in oil-water mixtures it appears to be maintained for comparatively high gradients, doubtless because of the greater viscosity and incompressibility of the oil droplets compared to gas bubbles. This is further confirmed by the curves of Fig. 6, which for practically 100 per cent water in effluent indicate a maximum water saturation that is progressively lower for increasing oil-water viscosity ratios.

The permeabilities of the sands discussed in this paper were low enough to be in the range of actual producing sands, so that the relationships established, together with those for gas-liquid mixtures, may now be regarded as applying to the entire range of unconsolidated sands.

Experiments recently completed in this laboratory on the flow of gas-liquid mixtures through consolidated sandstone are in agreement with the conclusion expressed in this paper that it is the characteristics of the sand, rather than the properties of the fluids, that are important in determining the details of the permeability-saturation relation.

G. D. Hobson,* London, England (written discussion).—The method used for determining the displacement pressure is open to some criticism, for it appears that there will be some uncertainty about the lowest position of the continuous oil within the sand. Even resistance measurements will not locate the position of the oil accurately. Admittedly the uncertainty may not be important with fine sands, but it will be where the displacement pressure is low.

It would have been preferable to plot the data in Fig. 6 for a given pressure gradient or total throughput of liquid, for when considering data that are affected by so many variables, as many variables as possible should be maintained constant, otherwise the picture becomes very complicated.

The displacement pressure is not "the minimum pressure differential that suffices to force oil *through* the sand. . . . " It is the minimum pressure required to force oil *into* the water-filled sand. However, there is little doubt that it is proportional to the pressure required to cause movement of the oil within the sand. It is very important to distinguish between forcing oil into a sand and moving it when it is within the sand. Simple analysis of the problem shows that the pressure necessary to move oil within the sand will be determined by the increase in curvature that must be imposed on a globule to cause it to pass through the pores where they are smaller than the globule in its free state; i.e., if it does not fill the larger parts of the pores, or in its equilibrium state if it presses against the pore walls. In the case of uniform spheres in close packing, if we take the displacement pressure as the pressure that will just cause continuous entry of oil into the pores, it would appear that the maximum curvature changes will involve a pressure oscillation of 0.3 of the displacement pressure, in the absence of resisting factors other than interfacial tensional.

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* Department of Geology, Imperial College of Science and Technology.

Experimental data regarding the effects of density differences would have been of great interest in view of the choice of vertically downward movement in these experiments. Comparison of the values of S (water concentration within the sand) for given oil-water flow ratios and over-all rates of flow upward and downward would have given a clue to the magnitude of the buoyancy effect in relation to the interfacial tensional forces that must be overcome in moving oil within a sand. For the conditions indicated above, S will be greater for downward flow than for upward flow.

M. C. Leverett (written discussion).—The maximum uncertainty in determination of the displacement pressure due to lack of knowledge of the position to which the oil penetrated the sand was always less than 0.2 cm. mercury. Since the displacement pressures were more than ten times this uncertainty and the system was insensitive to small changes in the group $\pi N/PD$, no appreciable change in the results would have appeared had π been more accurately measured.

Mr. Hobson correctly distinguishes between the pressure required to force oil into a water-saturated sand and that required to move oil within the sand. This distinction was, of course, appreciated early in the work described here.

The data appearing in Fig. 6 are replotted from those of Figs. 4 and 5. They were taken at approximately the same pressure gradient.

Exploratory experiments to determine the magnitude of the "buoyancy effect" showed that S (water saturation) was higher for upward than for downward flow, in accordance with theory. The difference was, however, small. Additional experiments, not reported in this paper, indicate that interfacial forces are considerably stronger than those due to the difference in densities between the liquids used in these experiments.

Effect of Pressure Reduction upon Core Saturation

By H. G. Botset* and M. Muskat*

(San Antonio Meeting, October, 1938)

Any information that will increase the accuracy of our knowledge of the conditions prevailing in petroleum reservoirs should be of direct value in the determination of the proper operating technique as well as in the estimation of reserves and of ultimate production. The obvious method of obtaining this information is by studying a sample of the reservoir rock and its contents. In any such study, the problem of primary importance and maximum difficulty is that of getting the core to the surface in such a manner that its original fluid content is undisturbed, which has so far proved to be an impossible task. Though it might be rash to say this will never be done, it is certainly safe to assume that a method for the recovery of a core at the surface in its undisturbed original state may not be developed in the immediate future, and certainly will not be forthcoming without a great deal of costly experimentation.

Therefore any information that may be obtained that will help to correlate the state of a core (its fluid saturation) at the surface with its condition at the time it was drilled should be of value to the petroleum industry. The experiments described in this paper were undertaken with the purpose of determining, if possible, any relationship that might exist between the saturation of a core at the surface and its original fluid content. No consideration has been given to the question of contamination by penetration of drilling water, since this problem has been extensively studied by other investigators.[1–3] Furthermore, it was regarded as outside the scope of these experiments, which were concerned only with the effect of pressure reduction upon the liquid content of cores.

In an experimental study of this sort involving a large number of variables, accurate control of all factors is very important. The essential and obvious procedure is to vary systematically one factor or condition while keeping all the others constant, which necessarily involves a rather protracted and sometimes tedious experimental program.

The procedure adopted was essentially very simple, and consisted merely in filling a given core with fluid (gas and oil, gas and water, or

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[1] References are at the end of the paper.

gas, water and oil) at the desired pressure; then reducing the pressure to atmospheric at a suitable rate and determining the final liquid saturation of the core.

The variables involved in this procedure are: the porosity of the core, its permeability, the nature of the liquid (or liquids) and gas, the saturation pressure, and the rate of pressure reduction. The variation of only one factor at a time makes it necessary to perform a whole series of experiments on a single core, otherwise it would be difficult to correlate results with porosity or permeability. Consequently, the experiments were so designed as to permit the repeated use of a given core. A further limitation on the experimental technique was the necessity for accurately weighing the core to determine its porosity and saturation. This restricted the core to a size that could be conveniently handled and weighed on an analytical balance. The core used was 3.2 cm. long and 2.7 cm. in diameter, the total volume thus being 18.3 c.c. (This varied slightly, of course, from core to core.)

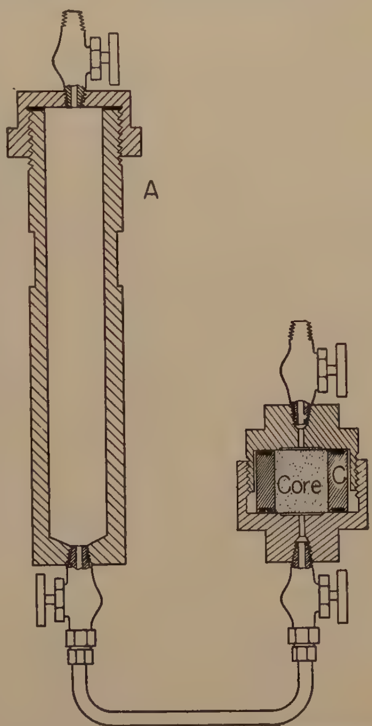

Fig. 1.—Apparatus for saturating cores.

Apparatus

The apparatus used for saturating the core was very simple (Fig. 1). It was designed to stand a pressure of 3000 lb. per sq. in., and was made of stainless steel to eliminate the possibility of corrosion when water was being used. The cylinder *A* was the oil reservoir and had a capacity of about 130 c.c. It was made long and narrow so that there would be a comparatively small area of contact between the oil and the gas. This reservoir was connected by means of the brass needle valves and copper tubing to the core holder *B*. Within this core holder is a stainless-steel cylinder *C*, whose inside diameter is such that a very gentle pressure is required to slide the core into the cylinder. The ends of the cylinder are provided with gaskets to prevent by-passing of the fluid along the outside. The necessity for weighing the core to determine its fluid content prevented the use of any sealing material to hold the core in the cylinder. Therefore this close, sliding fit was used, with the assumption that there would not be excessive by-passing of the fluid

between the cylinder wall and the core. The experimental results appear to justify this assumption.

Experimental Technique

The method of determining the pore volume of a core also served to check on the performance of the apparatus. The core was dried and weighed to a milligram on an analytical balance. It was then placed in the core holder and filled repeatedly with carbon dioxide from a pressure cylinder at approximately 900-lb. gauge. This served to flush out the air contained in the pores and to fill them with carbon dioxide. The reservoir was then filled with distilled water and attached to the core holder. The water was allowed to seep slowly into the core holder from below, displacing the carbon dioxide, which escaped through the valve at the top. When the water began to flow from the valve on top of the core holder this valve was closed and 600 or 700 lb. pressure was placed on the system by connecting the reservoir to the carbon dioxide tank. This pressure was maintained for 15 or 20 min. while the water was allowed to flow dropwise from the valve at the top of the core holder. When about 25 c.c. of water had flowed through the core holder, the pressure was reduced to atmospheric and the core removed from the holder. The excess water was wiped from the core by quickly touching the surface with a dry towel and the core was placed in a glass weighing bottle and weighed. Knowing the temperature, the volume of water in the core was calculated. This, of course, was the pore volume. The core was then dried in an oven and the procedure repeated. The consistency of results obtained showed that this method was really adequate to fill all the pores of the core. The weights of water in three determinations on a Berea sandstone core were 1.962, 1.951 and 1.977 grams. The maximum variation here is 0.8 per cent. On two other Berea sandstone cores duplicate tests gave pore volumes of 3.610 and 3.606 c.c. on one core; 3.582 and 3.594 c.c. on the other. Porosity measurements on two Nichols Buff sandstone cores gave, on one core, 4.061 and 4.059 c.c. pore volume; on the other, 4.091 and 4.087 c.c. The results on all of these cores were very close to porosity determinations made in the usual way.

The saturation experiments were performed in a manner essentially similar to that used in determining the pore volume. In the preliminary experiments water was the liquid used, since the core could be cleaned and made ready for a new experiment by simply drying in an oven for an hour or so, while the use of an oil such as kerosene involved the employment of a soxhlet extraction with subsequent oven drying, which lengthened considerably the time required for a given experiment. When water alone was used as the saturating liquid, the gas was carbon dioxide. When kerosene was used the gas was either carbon dioxide or a natural

gas from the city gas lines, analyzing about 83 per cent CH_4, 16 per cent C_2H_6 and 1 per cent N_2.

The procedure for the saturation experiments was as follows: The core was placed in the holder and the pores filled with gas by the process described for the determination of the pore volume. The reservoir was almost filled with liquid and connected to the gas supply by copper tubing, then the liquid was saturated with the desired gas (CO_2 or natural gas compressed into a pressure cylinder) at the desired pressure. The reservoir cylinder was then connected to the core holder and the liquid allowed to flow very slowly through the core at a pressure appreciably in excess (20 to 100 lb.) of the saturation pressure. Previous experiments on the flow of gas-liquid mixtures through sands[4] had shown that this method was adequate to saturate the core with liquid. When 50 c.c. of liquid had flowed through the core the pressure tank was closed off and the pressure on the core was reduced to atmospheric at any desired rate. As soon as atmospheric pressure was reached the core holder was disconnected from the system and the core removed from the holder, quickly wiped with a cloth just sufficiently to remove the excess liquid on the surface, placed in a weighing bottle and weighed. Knowing the weight and density of liquid in the core, as well as the pore volume, the saturation was easily calculated.

In order to simplify the experiments, the cores were cut from only two different sandstones, the Berea and Nichols Buff. Two cores were prepared from each of these sandstones. The pertinent data on these cores are contained in Table 1.

TABLE 1.—*Physical Data on Sandstone Cores*

	Berea Sandstone		Nichols Buff Sandstone	
	Core 1	Core 2	Core 1	Core 2
Total volume, c.c.	18.79	18.85	18.51	18.87
Pore volume, c.c.	3.588	3.608	4.060	4.089
Effective porosity, per cent	19.10	19.13	21.94	21.67
Permeability, darcies	0.23	0.23	0.48	0.48

The final saturation obtained in a number of preliminary experiments on Berea sandstone, in which the fluids were water and carbon dioxide, averaged very close to 65.5 per cent for saturation pressures ranging from 100 to 800 lb. per sq. in. gauge. In similar experiments using kerosene and natural gas at saturation pressures of about 1700 lb. per sq. in. the final saturation averaged 76.9 per cent. The average final saturation for five experiments on Nichols Buff sandstone, with kerosene and natural

gas as the fluids, was 76.2 per cent. In these experiments the pressure on the core was reduced at a comparatively slow rate to simulate the gradual pressure drop experienced as a core is brought up a well. However, for these first experiments there was not available a suitable means of controlling the rate of pressure drop at the higher pressures.

After a suitable pressure regulator had been obtained, which permits close control of output pressures up to 5000 lb. for input pressures up to 5500 lb. per sq. in., a more accurate regulation of pressure conditions was possible. In general, the rate of decrease of pressure on the core was maintained at about 15 lb. per min., which corresponds roughly to the rate at which a core barrel is brought up a well. It turns out that in this region the rate of pressure decline is not very critical and appreciable variations in the rate result in negligible variations in final saturation.

Effect of Water Content on Loss of Oil

Since practically all oil-field cores contain three fluids—gas, oil, and water[5,6]—the first set of experiments was made with cores containing all three. Water was introduced into the cores in a very simple manner. The dry core was placed on end in a flat dish containing a little distilled water. The water rose by capillarity and gradually saturated the core. When the entire core appeared to be wet it was placed in a glass flask and evacuated by a Hyvac pump. This evacuation produced a generous evolution of gas bubbles over the entire surface of the core, showing that all pores of the core had by no means been completely filled with water. After the flask had been pumped down to a pressure of a few millimeters of mercury, it was connected to a supply of natural gas and filled to atmospheric pressure. This process was repeated several times to insure a practically complete elimination of air from the pores of the core. Knowing the pore volume of the core, the weight of water required to fill it to a given saturation was easily calculated. The core was weighed at intervals during the evacuation process until the desired weight was reached to within a few milligrams. The core was accurately weighed, placed in the core holder, and subjected to the treatment described above for determining the kerosene saturation, care being taken to keep the fluid velocities through the core at a very low value, to prevent flushing out any of the contained water. If even a minute amount of water was displaced from the core, it was immediately evidenced, upon opening the core holder, by the presence of tiny droplets of water on the inside of the holder. The core was removed and weighed, the difference between this weight and that when core contained only water giving the weight of oil from which was calculated the oil volume and oil saturation.

Series of experiments were run on both Berea and Nichols Buff sandstone cores. The results are contained in Table 2, and plotted in Figs. 2 and 3. The experiments showed that it is possible to have a water

saturation of 60 per cent and still have no water expelled when the pressure is reduced at the rate of 15 lb. per sq. in. per minute.

TABLE 2.—*Cores Containing Water and Kerosene*

Saturation Pressure, Lb. per Sq. In.	Water Saturation, Per Cent	Final Kerosene Saturation, Per Cent Pore Space	Final Total Liquid Saturation, Per Cent	Final Kerosene Saturation, Per Cent Initial Kerosene	Kerosene Produced, Per Cent Initial Kerosene Present
BEREA SANDSTONE					
1,500	45.7	22.7	68.4	41.8	58.2
1,350	39.1	33.3	72.5	54.7	45.3
1,260	32.7	40.4	73.1	60.0	40.3
1,200	15.6	57.3	72.8	67.9	32.1
1,200	60.0	10.7	70.7	26.7	73.3
1,100	21.6	52.9	74.5	67.5	32.5
900	33.3	32.3	65.7	48.4	51.6
900	23.3	46.3	69.5	60.3	39.7
900	47.1	23.2	70.2	43.8	56.2
NICHOLS BUFF SANDSTONE					
1,000	58.3	15.4	73.8	36.9	63.1
980	49.2	21.8	70.9	42.9	57.2
980	44.0	30.4	74.4	54.3	45.7
920	39.1	29.5	68.6	48.5	51.5
900	8.3	62.1	74.1	67.7	32.3
900	17.6	47.7	68.8	57.9	42.1
900	29.8	38.9	68.8	55.4	44.6
900	41.7	25.6	67.4	43.9	56.1
900	21.4	50.3	71.7	64.0	36.0
900	14.5	55.4	69.9	64.8	35.1

The table shows that the final total liquid saturation is essentially constant, regardless of the amount of water initially present in the core. This means that the higher the water saturation, the larger the percentage of kerosene that is produced, or that higher water saturations will result in higher recovery efficiencies for the oil. This statement, which at first may seem rather questionable, becomes reasonable when it is recalled that the water is contained in the smaller pores and re-entrant angles between the sand grains where there is little, if any, flow during production. The gas, in coming out of solution in the oil, will tend to expand into the larger pores and push the oil out of them, leaving the very small pores only slightly affected if at all. When the sand contains only a small amount of water it occupies the finest of the pores and capillary spaces; as the percentage of water increases it occupies more and more of the larger pores, and at high water saturations forces the oil to occupy only the very largest pores, where the producing or displacing forces are most effective, thus resulting in a more efficient production of the oil.

In fact, the system behaves as though it contained a fixed group of large pores, which can be freed of liquid as long as the order of magnitude of the absolute pressure and the pressure gradients is kept fixed. Until the water content becomes so high that it extends into this group no

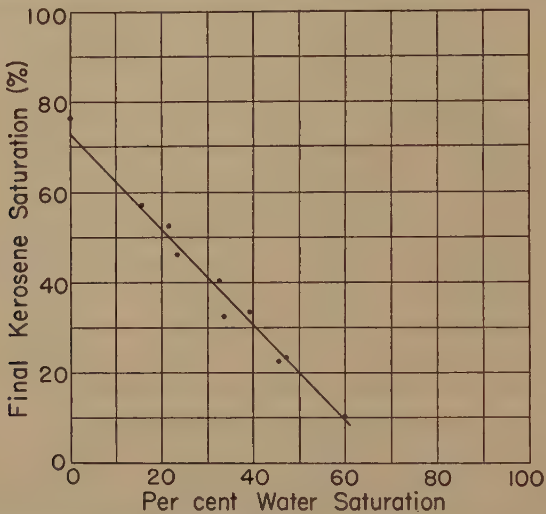

FIG. 2.—RELATION BETWEEN KEROSENE AND WATER SATURATION FOR BEREA SANDSTONE.

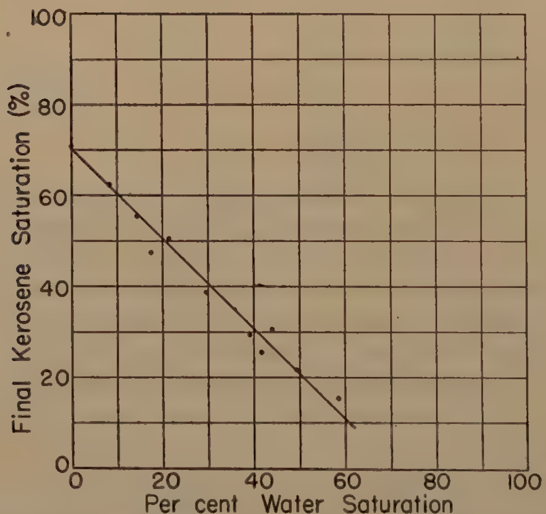

FIG. 3.—RELATION BETWEEN KEROSENE AND WATER SATURATION FOR NICHOLS BUFF SANDSTONE.

water will be produced, and the final saturation of the oil will decrease linearly with the water content. For still higher water saturations, it is probable that the oil recovery will be practically complete and that some of the water will also be expelled during the production, although the

present apparatus is unfortunately not suited to studying cores with very high water concentrations. This relation between water saturation and the fractional oil production is shown in Fig. 4, the data also being taken from Table 2. Although a strictly linear increase of fractional oil recovery with water saturation is not consistent with a linear decrease of the final oil saturation, the straight lines in Figs. 2 to 4 do represent the data with sufficient accuracy for all practical purposes.

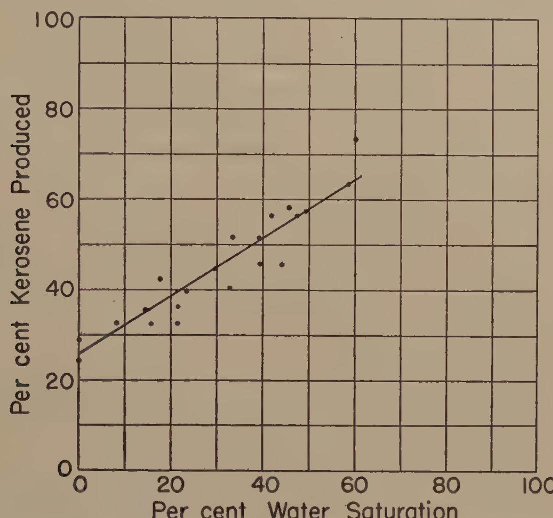

FIG. 4.—RELATION BETWEEN WATER SATURATION AND KEROSENE PRODUCTION.

VARIATION OF THE RESIDUAL OIL WITH THE ABSOLUTE PRESSURE

As the saturation pressures and rates of production for the experiments discussed in the last section were all of the same order of magnitude, a more detailed study was made to see whether the absolute value of saturation pressure would greatly affect the results. This question is important from a practical point of view in seeing whether the loss of oil in bringing a core up a well should vary materially with the depth of the sand from which the core was taken. A series of experiments was therefore performed with the Nichols Buff sandstone core, filled with kerosene and saturated with natural gas at various pressures. Since only the effect of the pressure was of interest here, no water was introduced into the cores.

The results are shown in Fig. 5. From the very slow variation of the ultimate kerosene saturation with the saturation pressure, especially at the higher pressures, it will be clear that the absolute pressure will not greatly affect the amount of oil expelled while the core is being brought up from the well. This result essentially means that the successive additions of gas to the kerosene, brought about by the increase of the

saturation pressure, will result in decreasing increments of additional oil expulsion. In terms of the gas-oil ratio during the course of the expulsion of the oil, this implies that the final stages of the expulsion are associated with the very high gas-oil ratios. From a production standpoint, this means a very inefficient recovery of the oil in the later stages of the recovery.

It is interesting to note that these results confirm the implications of the original studies made at this laboratory on the flow of gas-liquid

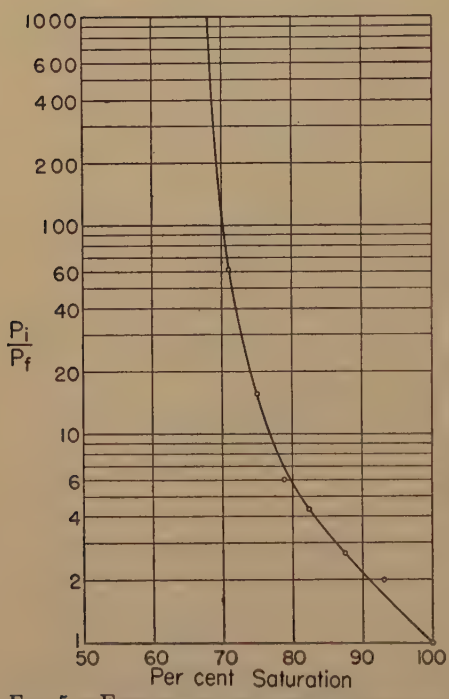

Fig. 5.—Effect of saturation pressure on final saturation.

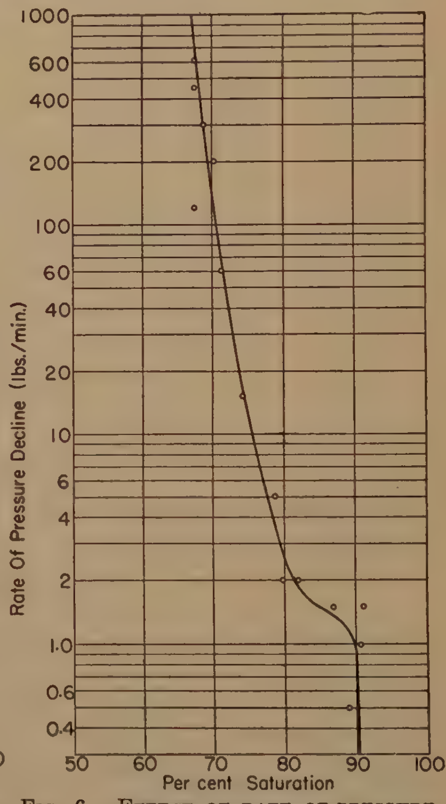

Fig. 6.—Effect of rate of pressure decline on final saturation.

mixtures through unconsolidated sands,[4] wherein it was found that the gas permeability increases very rapidly with decreasing liquid content of the pores. In fact, a theoretical calculation of the relation between the final liquid content and the saturation pressure, similar to that shown in Fig. 15 of the paper cited above, gave results of the same order as shown in Fig. 5. As was to be expected, the agreement was not exact, since the data on permeability versus liquid saturation that were used here were taken from the earlier paper, for which they had been derived for unconsolidated sands.

Liquid Recovery versus Rate of Pressure Decline

It is generally recognized that the expulsion of liquid by gas from the pores of the sand is largely determined by a balance between the capillary forces tending to retain the liquid in the smaller parts of the pores and the pressure gradients associated with the natural flow of the gas, which tends to drive out the liquid as though it were an ordinary viscous fluid. These gradients in turn are determined by the rate at which the pressures at the boundaries of the system are permitted to decline. Experiments were performed, therefore, to see how the loss of oil from a core would be affected by the rate of pressure decline. Again in these experiments, no water was introduced into the cores, as only the effect of the rate of pressure decline was of special interest. The results are shown in Fig. 6.

As is to be expected from physical considerations, higher rates of pressure decline tend to result in greater recoveries of oil. As previously suggested, this simply means that the higher pressure gradients associated with the higher rates of pressure decline are able to overcome the surface-tension forces in a larger number of the pores than are the lower pressure gradients.

The detailed variation of ultimate liquid saturation with the rate of pressure decline must obviously depend upon the distribution of the pore sizes within the sand. If the gradation of pore sizes is continuous, increasing increments of the pressure gradient should result in continuously increasing oil recoveries. If, however, the pore-size distribution is largely concentrated about pores of large size and pores of small size, the growth of recovery with increasing pressure gradients will become small after the large pores have been depleted, and only when very much higher gradients are imposed on the system will appreciable depletion of the small pores take place. This is apparently the situation involved in the Nichols Buff sandstone core used in the present study. Thus at rates of pressure decline below about 1 to 1.5 lb. per min., a minimum production is obtained, which is independent of the rate of pressure decline. At rates only slightly higher, there is a large increase in production, which implies a large number of pores of nearly the same size which are flushed out at this more or less critical rate between 1 and 2 lb. per min. At higher rates of pressure reduction the curve flattens out and very large increases in rate are necessary to obtain very small increases in production. Moreover, this picture fits in also with the results discussed above on the relation between the oil recovery and the water content. For if there were a flat distribution of pore sizes in these cores, it would be expected that some production of water would have been observed for saturations below 60 per cent. Nor would the recovery of the oil have been so definitely independent of the water content up to such high saturations of water.

As just mentioned, at very low rates of pressure decline, Fig. 6 shows a slow variation of the recovery with the rate of decline. In fact, the data indicate an asymptotic limit of 10 per cent recovery, even though the rate of pressure decline becomes vanishingly small. This limit corresponds to the equilibrium saturation of similar sandstone cores, as found in some preliminary experiments on consolidated sands that were carried through in the same manner as were those on unconsolidated sands.[4] Thus, as the unconsolidated sands originally indicated, there appears to be a minimum recovery of liquid associated with the locking of the gas in the pores until the liquid saturation falls to its "equilibrium" value. For greater recoveries than these, it is necessary to have a mass flow of the gas and a dragging of the liquid through the pores by the pressure gradients inducing the flow of the gas.

General Discussion

While from the point of view of the problem of bringing a core up a well bore, the present study indicates the specific result that the production should be of the order of 25 to 30 per cent, with little or no loss of water unless the sands have abnormally high water contents, the experiments are also of interest from the point of view of general production problems. For in principle the process of bringing a core up a well is nothing more than permitting a small sample of the reservoir to go through its complete production history. However, the gradients in such a process are very much higher than anything that would occur in an ordinary producing sand except in the immediate vicinity of the well bore. As Fig. 6 shows, such an accelerated history will lead to recoveries considerably higher than will be determined by the main body of the sand at great distances from the well bore. Unfortunately, advantage cannot be taken of the greater recoveries possible under the high rate of pressure decline, but one must rather accept the low rates that will obtain in practice and study the system under such conditions. From this point of view, experiments of the type described here with the associated technique should provide a means of predicting the order of magnitude of the ultimate recoveries when the rates of pressure decline are kept at very low values. Because of the asymptotic behavior of the curve of Fig. 6 at very low rates, it is fortunately not necessary to keep the rate of decline down to infinitesimal values, and experiments in which the pressure is released over an interval of 24 to 48 hr. should suffice to give results of reasonable reliability.

The present study, therefore, provides a technique for laboratory determination of the probable ultimate recovery to be obtained from oil reservoirs. Of course, in such experiments it would be desirable that samples of the actual oil and gas as well as the cores from the producing pay be used rather than such idealized fluids and porous media as have

served the purpose of the present study. In fact, general field experience of obtaining recoveries of the order of 20 to 35 per cent directly indicates that the results will vary appreciably with the nature of the sand, so that from a quantitative point of view actual cores from the producing pay would be necessary to give trustworthy results.

Fig. 5 also is of interest with regard to general production practice in showing the inefficiency of excessive amounts of gas in expelling commensurate quantities of the fluid content of the rock. In fact, a specific experiment in which a core filled with kerosene saturated to 900 lb. pressure was resaturated with gas to 900 lb. after an initial recovery experiment gave a final saturation of kerosene that was only negligibly different from that obtained with the initial gas content. Again, the quantitative effects of this kind will depend upon the nature of the pore-size distribution. But the qualitative result that one must expect an extremely slow variation of oil recovery with total amount of dissolved gas appears to be definitely established.

Acknowledgments

The authors wish to thank Dr. P. D. Foote, Executive Vice President of the Gulf Research & Development Co., for permission to publish this paper.

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DISCUSSION

(*Paul Weaver presiding*)

R. L. Huntington,* Norman, Okla.—What method was used in saturating the crude oil with gas before the core was wet with this gas-saturated crude?

H. G. Botset (written discussion).—The oil was saturated with gas by connecting the oil reservoir *A*, in Fig. 1, to the tank of compressed gas through flexible copper tubing and a reducing valve. The reducing valve was set at the desired pressure and the reservoir was shaken until the oil was saturated.

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* Director, School of Chemical Engineering, University of Oklahoma.

Interfacial Tension between Water and Oil under Reservoir Conditions

By C. R. Hocott*

(San Antonio Meeting, October, 1938)

The distribution and movement of fluids in oil reservoirs are influenced to a great extent by capillary forces, which depend upon the size and shape of the pores in the reservoir rock, the surface characteristics of the rock, and the interfacial tension between the fluid phases. This paper presents the results of an investigation of the interfacial tension between salt water and crude oil containing dissolved gas under reservoir conditions.

Apparatus and Procedure

In the preliminary phases of this investigation, it was found that a scum formed at the oil-water interface, which made measurement of interfacial tension by either the ring or capillary rise methods unreliable. Accordingly, the drop-weight method, in which a fresh interface is continuously formed, was selected. In this method, a tip through which drops of one fluid can be expelled is immersed in a second fluid. At the instant that the drop becomes large enough to fall, the gravitational force tending to pull away the drop exactly balances the interfacial force tending to hold it. From the size of the drop, the dimensions of the tip, and the density of the two fluid phases, the interfacial tension may be calculated.

The apparatus consists of a circulating pump for bringing the oil to equilibrium with gas at the desired pressure, a displacement pump for forming the drops, an interfacial tension cell in which the drops are formed, and a density cell to determine the density of the oil. The density of the water is determined separately in another apparatus. A flow diagram of the assembled equipment is shown in Fig. 1.

The interfacial tension cell contains a stainless-steel dropping tip suspended from the top and extending below the surface of the oil. The tip is a cylindrical rod with a small hole in the center through which the water was forced to form the drop on the lower face. The walls of the tip were highly polished, to prevent the water on the tip from creeping up the side and increasing the effective diameter. The face of the tip, how-

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ever, was roughened, so that the tip would remain water wet throughout a series of determinations. The roughening was accomplished by scratching the face of the tip in two perpendicular directions by rubbing it on No. 40 carborundum powder immersed in water on a flat metal surface. The cell also contains a pair of insulated electrodes placed far enough below the tip not to interfere with drop formation, yet always above the water level. When the drop falls from the tip, it bridges the gap between the electrodes and is detected by a buzzer in the electrode circuit.

The drops were formed by means of a small displacement pump which withdraws water from the bottom of the interfacial tension cell and forces it back through the tip without changing the volume of the system. The first part of the drop may be formed fairly rapidly, but in order to obtain accurate results the last portion of the drop must be formed very slowly.

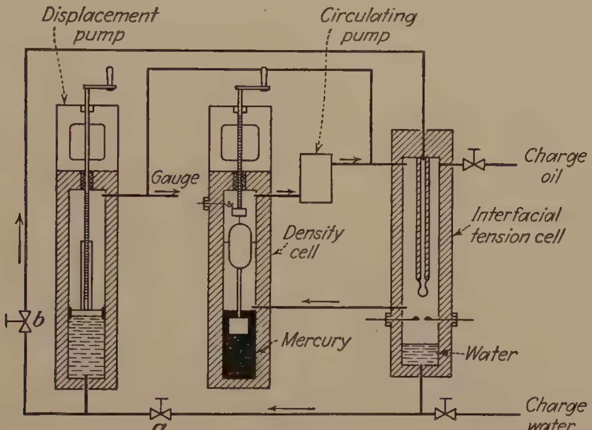

FIG. 1.—FLOW DIAGRAM OF INTERFACIAL TENSION APPARATUS.

The volume of the drop was determined from readings of the vernier of the pump between successive drops. The drop volumes were reproducible to about 0.002 c.c., which is within ± 0.5 per cent of the average size of the drop. This pump is also used to bring the oil and water to equilibrium by forcing the water through the tip several times fairly rapidly before the drop volumes are measured.

The density cell contains an insulated traveling electrode and a metal hydrometer. The hydrometer consists of two cylindrical plummets connected by a steel rod of small diameter. The upper plummet, made of aluminum, is immersed in oil, and the lower, made of stainless steel, is immersed in mercury. The immersion of the hydrometer is a function of the density difference between mercury and the oil. The position was determined by moving the traveling electrode until it touched the hydrometer, completing a circuit through a buzzer; the calibrated scale on the electrode was then read. The density of the oil was reproducible

to about 0.003 gram per cubic centimeter, which limited the over-all accuracy of the measurements of interfacial tension to approximately 2 per cent.

Determinations were made in a constant-temperature water bath. The apparatus was charged by first adding water and forcing a few drops through the tip, after which, with the valve to the tip closed, oil was charged to the desired pressure. Determinations were made over a range of pressures from atmospheric to above the pressure of the reservoir from which the sample was taken. The pressure was decreased by bleeding gas off through the charging line, the circulating pump being used to bring the oil and gas to equilibrium as the pressure was increased or decreased.

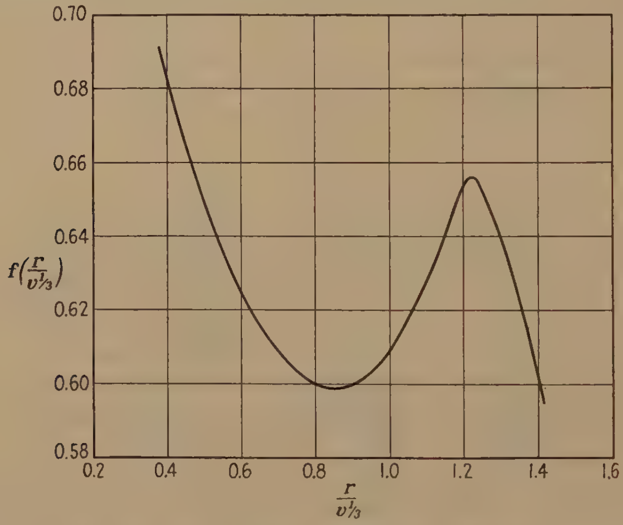

FIG. 2.—DROP VOLUME CORRECTION, EQUATION 1.

CALCULATIONS

The interfacial tension is calculated from the tip radius, drop volume, and oil and water densities. If the drop had the same radius as the tip and broke completely free from the tip, no correction would be needed. Actually, however, the drop pinches off and breaks considerably below the face of the tip, leaving a residual portion. Harkins and his coworkers have developed a correction for the fraction of the drop that falls as a function of the drop volume and tip radius.[1] The two curves developed by them are shown in Figs. 2 and 3. The equation for interfacial tension using the correction of Fig. 2 is

$$\gamma = \frac{v\Delta\rho g}{2\pi r f(r/v^{1/3})} \qquad [1]$$

[1] Harkins et al.: *Jnl.* Amer. Chem. Soc. (1916) **38**, 228–253; (1917) **39**, 354–364, 541–596; (1919) **41**, 499.

where γ = interfacial tension in dynes per centimeter.
v = drop volume in cubic centimeters.
$\Delta\rho$ = density difference between water and oil, grams per cubic centimeter.
g = acceleration due to gravity (c.g.s.).
r = tip radius in centimeters.
$f(r/v^{1/3})$ = correction read from Fig. 2.

So long as the ratio of the tip radius to the cube root of the drop volume is such as to be in the flat portion of the curve in Fig. 2 (i.e., 0.8–0.9), no further correction is needed. Four tips were made with diameters of 0.7, 1.0, 1.5, and 2.0 cm., in order that a tip size might be

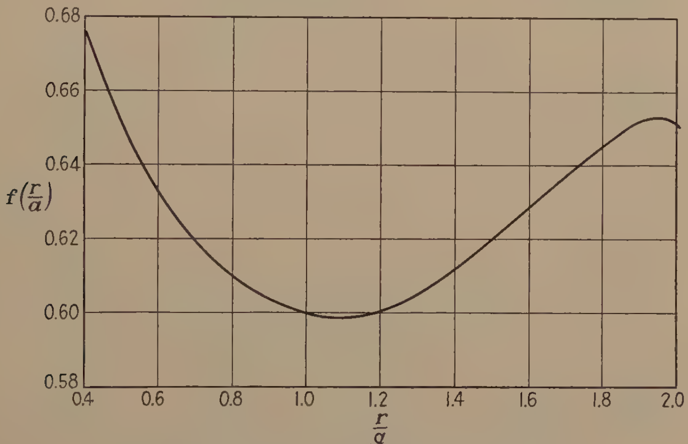

FIG. 3.—DROP VOLUME CORRECTION, EQUATION 2.

selected for each oil, so that the ratio would be as close as possible to the desired limits. However, other sizes of tips may be used provided the further correction shown in Fig. 3 is used. This correction is made by using the value of γ obtained in equation 1 and solving for a factor a from the equation

$$a = \sqrt{\frac{2\gamma}{g\Delta\rho}}$$

From the value of r/a, the correction $\psi(r/a)$ is read from Fig. 3, and the final equation becomes

$$\gamma = \frac{v\Delta\rho g}{2\pi r\psi(r/a)} \qquad [2]$$

The interfacial tension is solved for in this equation by trial and error, value of a being recalculated until constant γ is obtained.

Results

The interfacial tension between water and subsurface samples of oil from the following fields was determined: Anahuac, Chambers County,

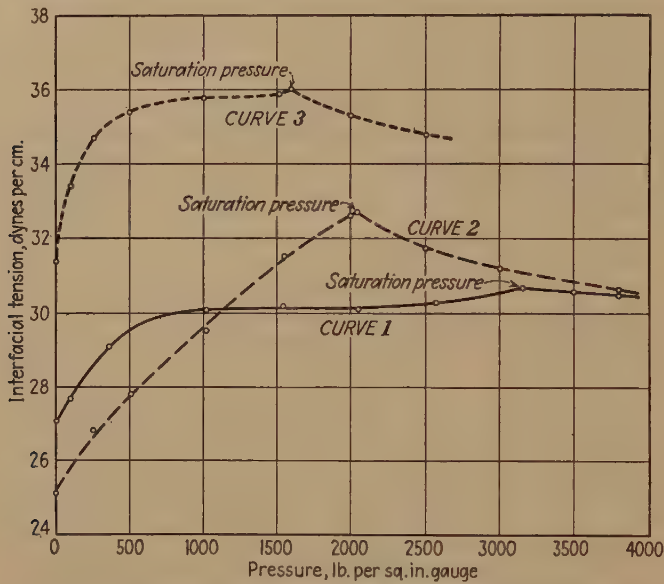

Fig. 4.—Interfacial tension between oil and water.

Texas; Conroe, Montgomery County, Texas; and K.M.A., Archer and Wichita Counties, Texas. In each case, the determinations were made

Table 1.—*Tabulation of Results*

Interfacial Tension						Surface Tension			
Anahuac: 178° F.		Conroe: 170° F.		K.M.A.: 130° F.		78° F.		150° F.	
Pressure, Lb. per Sq. In.	Interfacial Tension, Dynes per Cm.	Pressure, Lb. per Sq. In.	Interfacial Tension, Dynes per Cm.	Pressure, Lb. per Sq. In.	Interfacial Tension, Dynes per Cm.	Pressure, Lb. per Sq. In.	Surface Tension, Dynes per Cm.	Pressure, Lb. per Sq. In.	Surface Tension, Dynes per Cm.
3800	30.5	3700	30.6	2500	34.8	0	74.1	0	67.5
3500	30.6	3000	31.2	2000	35.3	100	71.1	100	63.2
3150	30.7	2500	31.7	1590	36.0	250	66.5	250	58.8
2580	30.3	2000	32.6	1520	35.9	500	61.6	500	55.5
2050	30.1	1550	31.5	1000	35.8	1000	55.9	1000	50.4
1540	30.2	1020	29.5	770	35.7	1500	51.6	1500	46.5
1120	30.1	515	27.8	500	35.4	2000	47.9	2000	42.3
470	29.1	260	26.8	260	34.7	2700	44.1	2530	39.5
100	27.7	100	25.8	100	33.4	3000	42.2	3000	37.4
0	27.1	0	25.1	0	31.4	3500	40.3	3500	36.0

at reservoir temperature and at pressures from above the saturation pressure to atmospheric. Also, the surface tension of a subsurface sample of water against gas was determined at two temperatures. All data are tabulated in Table 1 and are shown graphically in Figs. 4 and 5.

Curve 1 in Fig. 4 shows data on a sample from the Anahuac field. Production is from the Frio sand in the lower Oligocene formation. The sample was taken at a depth of 6850 ft. and had a saturation pressure of 3120 lb. per sq. in. gauge at 178° F. When flashed to atmospheric pressure at 78° F., the sample yielded 640 cu. ft. of gas per barrel of residual oil. The specific gravity of the gas was 0.716, and the gravity of the oil

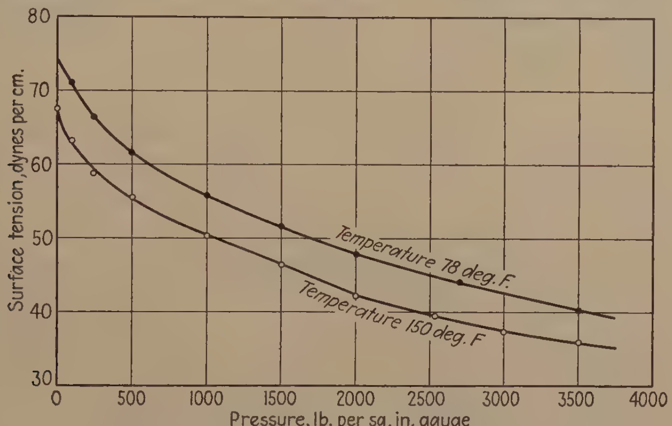

FIG. 5.—SURFACE TENSION OF WATER AGAINST GAS.

33.5° A.P.I. at 60° F. Hydrocarbon analyses on subsurface samples of the oil show the oil to be lean in the light hydrocarbons between methane and heptane.

Curve 2 shows data on a sample from the Conroe field. Production is from the lower Cockfield or Conroe sand in the Eocene-Tertiary formation. The sample was taken at a depth of 5000 ft. and had a saturation pressure of 2035 lb. per sq. in. gauge at 170° F. When flashed to atmospheric pressure at 78° F., the sample yielded 550 cu. ft. of gas per barrel of residual oil. The specific gravity of the gas was 0.862, and the gravity of the oil 36.9° A.P.I. at 60° F. The gas obtained under these conditions was fairly rich in the intermediate hydrocarbons, containing about 2.4 gal. of isobutane and heavier per 1000 cubic feet.

Curve 3 shows data on a sample from the K.M.A. field. Production is from the Kemp City lime in the Upper Pennsylvanian formation. The sample was taken at a depth of 3850 ft. and had a saturation pressure of 1570 lb. per sq. in. gauge at 130° F. When flashed to atmospheric pressure at 78° F., the sample yielded 650 cu. ft. of gas per barrel of residual oil. The specific gravity of the gas was 1.068, and the gravity of the oil 41.3° A.P.I. at 60° F.

Fig. 5 shows data on the surface tension of a subsurface sample of water against gas at two temperatures, 78° F. and 150° F. The gas, taken from the tubing of a gas well, was stripped at high pressure with activated charcoal and consisted mainly of methane with small amounts of ethane and propane.

Conclusions

From the results of this work, the following tentative conclusions may be drawn:

The interfacial tensions between water and the oils examined were all of about the same magnitude. Because the age and properties of the oils studied varied widely, it may be that the interfacial tension between water and most sweet crudes will be in this same range. No sour crudes were examined.

The quantity of gas in solution affects slightly the interfacial tension, which increases with the amount of dissolved gas. The effect of increasing the pressure on an oil containing a constant amount of dissolved gas is to decrease slightly the interfacial tension.

There is a rough trend between interfacial tension and the density of the oil, the higher gravity oils having lower interfacial tension against water.

The surface tension of water against gas is greatly influenced by the pressure of the gas, ranging from values about equal to the surface tension of water against air at atmospheric pressure (72 dynes per cm.) to values approaching the interfacial tension of water and crude oils at pressures in the neighborhood of 3000 to 4000 lb. per square inch.

DISCUSSION

(*W. E. Winn presiding*)

H. K. Livingston,* Austin, Tex. (written discussion).—The apparatus devised by Dr. Hocott is very ingenious, and the results that it is now possible to obtain by use of it will contribute much to proper analysis of reservoir conditions. It is to be hoped that more extensive data will be published in the future. It is interesting to note that Dr. Hocott has used Harkins's drop-weight method instead of the duNouy ring-pull device, which at first appears to lend itself to remote control more readily. Earlier equipment for measuring surface tension under pressure generally used the duNouy method with a solenoid and remote electric control.

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Surface Chemistry of Clays and Shales

By Allen D. Garrison*

(San Antonio Meeting, October, 1938)

The chemistry of clays and shales has been assuming increasing importance in the petroleum industry, and two factors have greatly influenced this trend. The first has been the growing evidence that the marine shales are source beds, and that the petroleum compounds have migrated to the sand reservoirs overlying or underlying these shales: the second has been the demand for drilling fluids better adapted to penetrate these marine shales without difficulty and expense.

Origin and General Composition of Clays and Shales

Clays, shales and surface soils are all closely related materials. They are mixtures of finely divided compounds formed during the weathering of the solid crust of the earth. Their nature is essentially colloidal; that is, their behavior is determined by the state of division of the materials and the surface reactions of the smallest grains. Many of their chemical changes affect only the exposed areas and do not involve the interior of the grains of matter. The extent of these reactions is more nearly proportional to the area of the substances than to their mass, therefore it is possible for a small amount of a material in an extremely fine state of division to completely dominate the character of the mixture.

More than 83 per cent of the crust of the earth is composed of three elements—oxygen, silicon and aluminum. Consequently, the corrosion products of the crust are predominantly aluminosilicates, or compounds of aluminum, silicon and oxygen.

If we add the compounds of six elements—iron, calcium, sodium, potassium, magnesium and hydrogen—more than 98 per cent of the crust has been accounted for. These six elements, together with the first three, also appear in soils, clays and shales.

But direct chemical analysis is of little value in describing the nature of such materials. Many chemical individuals may be present in variable amounts, and the extreme subdivision of any one of the individuals may contribute qualities that dominate the mixture.

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* Assistant Professor of Chemical Engineering and Physical Chemistry at Rice Institute, Houston, Texas.

According to a geochemical estimate of the lithosphere,[1] the solid crust that is available to chemical analysis and estimation and extends to a depth of about five miles below sea level, about 5 per cent of the earth's crust has weathered. About 4 per cent of the lithosphere may be classed as clay or shale, 1 per cent as limestone or sandstone, and the remaining 95 per cent as unattacked igneous rocks.

The chemical weathering of the igneous rocks has resulted largely from the attack of the two substances, water and atmospheric carbon dioxide. The feldspars and the hornblendes, which compose most of the igneous rocks, are not stable in the presence of these atmospheric agents and reactions take place that are similar to the following illustration, which is the accepted reaction for the formation of kaolinite, a clay mineral, from orthoclase, a feldspar:

$$\underset{\text{Orthoclase}}{K_2O\cdot Al_2O_3\cdot 6SiO_2} + H_2O \rightarrow \underset{\text{Kaolinite}}{H_2O\cdot Al_2O_3\cdot 2SiO_2} + K_2O\cdot 4SiO_2$$

The orthoclase and the kaolinite are chemical identities, having definite crystalline patterns. The potassium hydroxide released during the reaction is instrumental in rendering some of the silica (SiO_2) soluble enough to be washed away by rain.

Orthoclase is a familiar example of a large class of feldspar minerals. Chemical analyses of these minerals present a bewildering complexity, owing to a widespread tendency toward isomorphism. Iron may substitute for aluminum in almost any of its positions in the crystals. Since, in minerals, molecules have completely lost their identity and the atoms are spaced in regular patterns, the substitution of an indefinite number of iron atoms for an equal number of aluminum atoms at random spots in the structure makes for infinite chemical complexity. Magnesium may also take the place of aluminum, and sodium, calcium and potassium are scattered throughout the mineral structures in exchangeable positions. After weathering of the feldspar minerals, the resultant clay minerals exhibit the same isomorphism and bewildering complexity. But W. L. Bragg[2] is encouraging in this matter when he says: "On the other hand, when the structure is taken into account, the apparently bewildering varieties of composition are seen to fall into an extremely simple scheme."

Structure of Aluminosilicates

In spite of their complexity, the aluminosilicates may be classed in three simple structual groups: fiber structure, micaceous structure and framework structure. The first has rigid binding in only one direction; like the strands of a cord they resist separation in one direction but are

[1] References are at the end of the paper.

easily pulled apart in the other two directions. The fibrous zeolites are typical of this group. The second group has rigid binding in two directions and weak attachment in the third. They split easily into thin sheets, and frequently separate spontaneously in liquids. Mica, talc, kaolinite, the bentonites and pyrophyllite are among the micaceous minerals. Pauling[3] has shown that the easy cleavage of these minerals is readily explained by their structure. The third group has rigid binding in all directions in space. The structure may be compact and impermeable, or, like the framework zeolites used in water softening, the structure may be so open and porous that ions may move in and out of the spaces. Clays, shales and the surface soils contain all of these types, but in the smaller grain sizes the micaceous type predominates and is more likely to determine the behavior of the mixture.

The Clay Minerals

The typical minerals of clays and shales are micaceous in structure, consisting of thin hexagonal flakes with easy and perfect cleavage. There can be little doubt that they are all based upon the sheet of linked silicon-oxygen tetrahedra. The bonding in the plane of the sheet is

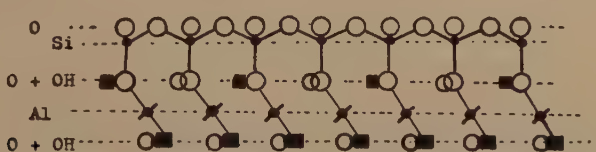

FIG. 1.—SIMPLIFIED DIAGRAM OF KAOLINITE.

strong. Mica consists of two sheets of silicon-oxygen tetrahedra cemented together with a sheet of aluminum atoms and hydroxide groups and these three-ply sheets are attached more loosely by layers of potassium atoms. When a sheet of mica is cut with a knife, the separation takes place at the weak plane of potassium atoms.

Ross and Kerr[4] distinguish four main groups of clay minerals: (1) the kaolin group, (2) the montmorillonite group (bentonite), (3) the potassium-bearing clays, (4) a more evasive group occurring in many shales. Grim, Bray and Bradley[5] have described a group, which they call "Illite" and which may be materials from group 3.

Definite data on crystal structure are available for only the first group.[6] Fig. 1 shows a simplified sketch of kaolinite, and provides a basis for description of what is known of the other groups, and for a discussion of the surface chemistry of the clay minerals. The figure represents a unit sheet of kaolinite in section. The very rigid binding through the sheet occurs near the top, where three of the four corners of each of the tetrahedra are linked together in rings that would appear as hexagons if

viewed from above. The fourth corner of each tetrahedron is downward and linked to the aluminum atoms, which in turn are linked on either side to oxygens and hydroxide groups. The pattern is continued indefinitely until the broken edge is encountered. The sheets lie in piles but are easily separated, as in mica. It is possible for these sheets to enter into chemical reactions as units, although they may contain indefinite numbers of atoms, depending on the sizes of the sheets. The chemical nature of the top of the sheet is different from that of the bottom, and both are radically different from the chemical reactions that may take place at the broken edges.

Other clay minerals resemble kaolinite, but their structures have not been solved. Montmorillonite is particularly interesting because it has found wide use in drilling fluids and has some of the properties of kaolinite exaggerated to the extreme. The ratio of $SiO_2:Al_2O_3$ in the chemical analysis is higher, being about 4:1, and the deficiency appears to be partly made up with calcium, sodium or magnesium. The chemical evidence that will be presented seems to indicate that the last three elements may be isomorphous with the aluminum in a structure that is much like kaolinite.

Surface Chemistry of the Clay Minerals

Retention of Water

Kelly, Jenny and Brown[7] have studied the extent to which soil colloids and minerals retain water and have explained their results in relation to the crystal structures. They present evidence that there are three ways of holding water in combination: (1) crystal water, (2) broken-bond water, (3) planar water.

The crystal water is combined into the crystal structure as part of the pattern. It is very firmly bound. Kaolinite must be heated to about 500° C. to drive out the crystal water and the anhydrous compounds that remain are totally unlike kaolinite. Water is formed by splitting out two of the hydroxyl groups in Fig. 1, leaving a single oxygen, and combining the other into H_2O. In all the low-temperature reactions through which clays and shales proceed, the crystal water remains intact.

Water attached to clay minerals, and which may be driven off below 350° to 400° C., is usually combined at the surface of the sheets or framework structures, and, therefore, classed as adsorbed water. This is a typical reaction in surface chemistry. The nature of the surface to which the water is attached determines the strength of bonding, the amount of water bound, and the temperature at which the water may be driven off.

Broken-bond water is that which is attached at the broken areas of the framework structures, at the broken edges or rims of the micaceous

structures, and at the smaller ends of the fibrous structures. Fine grinding of the particles increases the capacity to adsorb broken-bond water by increasing the areas over which the crystal patterns become discontinuous. On the other hand, it is possible to cleave the micaceous platelets, or split the fibrous structures without breaking the rigid crystal bonds, and, therefore, without increasing the broken-bond water. Kelly, Jenny and Brown have shown that the water held in combination by several typical minerals may be greatly multiplied by fine grinding, and that the temperature required to remove this broken-bond water is more than 200° higher than the normal boiling point of water. In the normal lives of clays and shales in nature, this type of water would not be removed, and it would increase when any natural grinding forces break the crystal structures.

Planar water is not rigidly attached to the clay minerals. It is held by weak electrostatic forces along the tops or bottoms of the flat plates of the micaceous minerals. In Fig. 1, the top and bottom of the sheet of kaolinite may be seen to consist of silica tetrahedra and aluminum octahedra, or tetrahedra, respectively. These areas are chemically saturated; their chemical combining power has been used up from the inside of the sheet, a condition that is not found at the broken edge, where some chemical combining power remains. The only forces remaining to attract water are weak electrostatic forces, which are due to slight surface polarity. Water held on these areas may evaporate almost as readily as free water.

It is planar water that causes the swelling of clays when wet and the shrinking when dry. Since it is almost as free as ordinary liquid water, the surface soil colloids attract water to these areas only when excess water is available, but lose it again when the air becomes dry. The attraction is strong enough to pry the sheets apart in many minerals, of which the bentonites form an extreme case. This is evidence that the top and bottom of the sheets attract water more strongly than they attract another sheet. Deep shales have had most of the water of this kind pressed out from between the sheets by the overburden, and frequently cause much trouble in drilling operations because they tend to swell by adsorption of the water of the drilling fluid as planar water.

Pauling[3] has pointed out that the sheets of a material like kaolinite are polar. The silica tetrahedra in the top layer are more negative than those of the bottom layer of aluminum and oxygen groups. This polarity would encourage the water to slip into the space between the plates. One may well imagine that the kaolinite is partly soluble in water in one direction in space but insoluble in the other two directions.

The bentonites have this swelling ability to the extreme. They are known to be sheet structures similar to kaolinite, but the ratio of silica to alumina is almost twice as large, and the deficiency is partly made up

by the oxides of potassium, sodium, calcium and magnesium. The chemical evidence is such that a prediction may be made that when the structure is better known these four metals will be found to be partly isomorphous with aluminum in a kaolinlike structure. This would greatly increase the polarity of the sheet, causing the bottom to assume a greater positive charge than the top, and thereby account for the great thickness of the water layers that may occur in the bentonites. Bradley, Grim and Clark[8] have obtained X-ray evidence that water may pile up between sheets of a sample of Wyoming bentonite to a thickness of 24 layers of molecules, merely under the influence of moist air. Bentonite may be said to be freely soluble in water in one direction in space, that perpendicular to the planes of the sheets. The double sheet structure sometimes assigned[15] having silica tetrahedra on each side could not have such polarity, and is not accepted by Bragg.[2]

Ionization and Base Exchange

The phenomenon of base exchange was first observed in the year 1845 by Thompson[9] and later was studied by Way.[10] Many papers have been published on the subject.[11] Bradfield[12] has shown that the colloidal aluminosilicic acids of the soil are relatively strong acids and may be titrated with bases much like any acid. Electrodialysis of soil colloids and bentonites yields relatively strong acids showing pH+ about 2 to 3 in water. These are colloidal acids; that is, the anions, or negative ions, consist of the colloidal clay sheet and hydrogen ions are released into the water.

The bottom of the colloidal kaolinite sheet is composed of oxygen and hydroxide groups forming a part of the crystal pattern (Fig. 1). This is the side that, according to Pauling, tends to be positive in polarity. It is evidently possible for the hydrogen ions of these bottom layers to ionize into the water just as those of any acid. The only difference between this acid and an ordinary soluble acid lies in the rigid lateral binding through the sheet, and the subsequent rigidity of the colloidal anion.

The bentonites yield particularly strong acids. The same increase in polarity that has been spoken of as the explanation of the extreme swelling in bentonites contributes to the easy release of the hydrogen ions and consequent acid strength.

The fact that the equivalent weight of the bentonite is not dependent on the particle size is evidence that the layers of water between the sheets are thick enough to permit the ions to move in and out.

When all the OH groups on the faces of the sheets are replaced by O-Na groups, the clay acid becomes a sodium clay salt. This occurs above a pH+ of about 9. The sodium ion escapes more easily than the

hydrogen ion, therefore the sodium clay is more inclined to be completely ionized, to have a higher total negative charge on the micell, or anion, and therefore to form more stable suspensions. Quantitative data have been presented by Jenny and Reitemeier[13] demonstrating that the extent of ionization of the colloidal clay salts increases in the order $Cs < Rb < NH_4 < K < Na < Li$ for the ions of single valence and $Ba < Sr < Ca < Mg$ for the ions of double valence. The hydrogen ions are more tenaciously attached than any of the metal ions mentioned above. Since the ionization of sodium and lithium clays is more complete than that of others, leaving sheets that have high negative charges, there is a decided tendency for these clays to split into a much larger number of thinner clay micells. The negative charges hold the clay sheets in suspension by electric repulsion and the kinetic molecular agitation keeps the platelets in perpetual Brownian movement.

The rivers of the earth thus carry the colloidal parts of the top soils and clays more readily if they are slightly alkaline and free of calcium and magnesium salts. At the point where the rivers enter the sea, the excess salt together with the plentiful supply of calcium and magnesium ions in sea water renders the colloidal clays unstable. The more tenacious absorption of the calcium and magnesium ions causes a reduction in negative charge and consequent enlargement of particles followed by precipitation. This process is one of the major causes of the great deltas of the earth.

The marine shales were once surface soils and clays. They underwent the deflocculation, transportation and sea-water reactions described above, and were buried below a heavy overburden of sediments. It is not surprising that many of them cause drilling difficulties. When exposed to fresh water again, particularly at high pH+ values and reduced pressures, they proceed to deflocculate, swell and contribute some of their exchangeable calcium and magnesium to the drilling clays. Aggravated cases are called heaving shales, but even the milder forms cause excessive expense if it is necessary to maintain high density in the drilling fluid in their penetration. Water must be added to dilute the colloids, and additional weighting material to maintain the density.

Cohesion and Gelling

The plastic flow of clay suspensions is well known, and the "thixotropic" state has been recognized recently.[14] The data[16] presented graphically in Fig. 2 will serve to throw more light on the nature of this phenomenon, which is essentially a surface problem.

California bentonite has been prepared in concentrations ranging from 4.5 to 6.5 per cent. The suspensions were allowed to age for several weeks and measurements were then made of the rate at which they gelled from the completely degelled condition.

The instrument used was a torsion wire gelometer, consisting of a brass cylinder of known dimensions suspended from a steel wire and provided with means of rotating the wire at the top through any angle. The cylinder was immersed in the bentonite suspension after it had been completely degelled by a motor-driven agitator. The bentonite was allowed a certain time to gel, after which the wire was rotated cautiously through a gradually increasing angle. A light pointer on the cylinder and one on the upper end of the wire made it possible to observe the force, which was just sufficient to shear the cylinder in the bentonite gel.

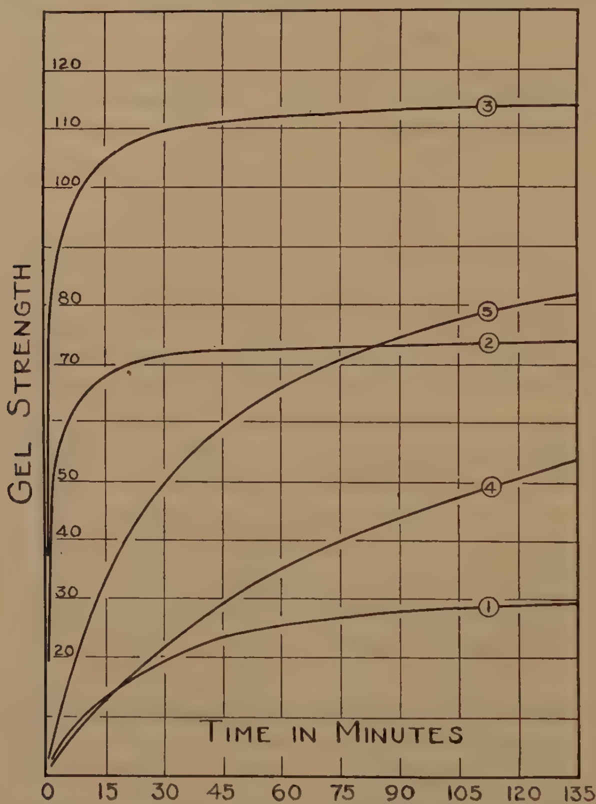

FIG. 2.—GEL STRENGTH IN RELATION TO TIME AND RATE OF REACTION.

Calibration of the wire and the cylinder made it possible to calculate the gel strength in absolute units; namely, dynes per square centimeter.

The gels formed more rapidly at first, the strength gradually approaching a constant value as time elapsed. Both the speed and the final strength increased with the bentonite percentages. The gelling was found to be following the relatively simple reaction equation:

$$S = \frac{S'kt}{1 + kt}$$

where S is the gel strength at time t, S' is the gel strength that is approached at very long times and k the rate constant. This equation indicates that the values of t/S should be directly proportional to time.

Fig. 3 presents the data plotted in another way. The slopes of the lines in Fig. 3 are the values of $1/S'$ and the intercepts are the values of $1/kS'$. In this way it was possible to evaluate the final gel strengths in each case, and the values of k the rate constants.

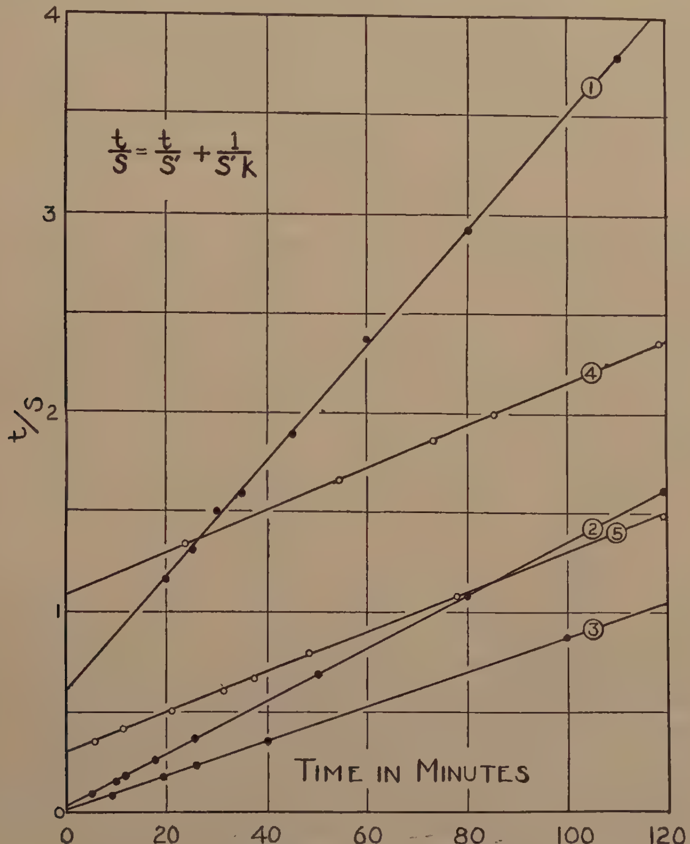

FIG. 3.—GEL STRENGTH AND RATE CONSTANTS.

The California bentonite had a natural pH+ value 9.2, and lines 1, 2 and 3 in Figs. 2 and 3 present the data of the 4.5, 5.5 and 6.5 percentages of the bentonite at this natural pH+ value. Measurements were made of similar suspensions at higher alkalinity by the same method. Table 1 shows the results of the determinations. It is evident that the ultimate strengths of the bentonite gels increase with each suspension as the pH+ values increase. The changes in the rate constants are not so regular, but there is a general tendency for the speed of gelling to fall off up to

about pH+ 10. and rise thereafter. This is direct evidence that the planar water is more effectively separating the colloidal sheets at pH+ values above 9.

This behavior of bentonite is significant because it is characteristic of all the colloidal minerals of clays and shales. It is the cause of the plastic character of clay and shale suspensions. During any measurement of viscosity, the gel is continually forming and being broken by the fluid motion. Consequently, the viscosity is higher at low rates of shear because the gel strength is permitted to rise, and lower at high rates of shear because the gel is kept more completely broken. It is one of the major factors in "gas-cutting" of drilling fluids, for a weak gel that forms rapidly prevents the rise and escape of the suspended gas. The effect on the settling of sand and suspended cuttings is obvious.

TABLE 1.—*Constants in Gelling Equations of Bentonite Suspensions*

Bentonite, Per Cent	Gel Strength and Rate Constant	pH+ 9.2	pH+ 9.3–9.5	pH+ 9.9–10	pH+ 10.8–11
4.5	S'	34.4	40.1	48.5	69.6
4.5	k	0.047	0.071	0.076	0.063
5.5	S'	74.4	82.2	129.9	152.7
5.5	k	0.75	0.22	0.13	0.18
6.5	S'	114.	141.	250.	268.
6.5	k	0.79	0.30	0.10	0.25

One of the very common treating agents used to reduce the "viscosity" of drilling fluids is sodium tannate. The lines numbered 4 on Figs. 2 and 3 were obtained after the addition of about 0.1 per cent of sodium tannate to the suspension containing 5.5 per cent of bentonite. The S' constant for these lines is 104, the rate constant is 0.0089, and the pH+ about 9.2 units. It is clear that the effect of the treatment is predominantly on the rate of gelling. The viscosity measured by any of the usual methods appears to be reduced, because the formation of the gel is retarded in speed but not in ultimate strength.

The same effect may be obtained to a lesser degree by more complete conversion of the clay minerals into the sodium salt. A sample of California bentonite was electrodialyzed to a pH+ of about 2.8, and then brought back to a pH+ of 9.9 with pure sodium hydroxide. The concentration was adjusted to 5.5 per cent and the gelling equation determined. Curves 5 on Figs. 2 and 3 show the results. The S' value was 99.7 and the gel rate constant k was 0.033; whereas the same condition prior to the removal of the exchangeable calcium and magnesium

had $S' = 129.9$ and $k = 0.130$. The same electrodialyzed sample gave $S' = 118$ and $k = 0.067$ at 10.7 pH+. It is clear that the removal of the weakly ionized calcium and magnesium from the exchangeable positions and the replacement by sodium has greatly reduced the gelling rate.

Interpretation of Gelling Data

The relationship between gel strength and time may be explained by a relatively simple mechanism. Smoluchowski[17] proposed a mathematical solution of the problem of the formation of colloidal aggregates from a colloidal dispersion. His formulation may be written:

$$N = \frac{n_0}{1 + kt}$$

where N represents the summation of all the aggregates after time t, starting with n_0 particles separately suspended at time zero. He shows how the constant k may be calculated.

One may assume that the bentonite suspension consists of n_0 particles shaken completely free of one another, and that they gel by becoming attached at a rate determined by Smoluchowski's equation. The gel is completely formed when there is but one aggregate to which all the particles are attached. The gel strength would thus be larger, the greater the number of the original particles. We may thus assume:

$$S = K(n_0 - N)$$

and substitution and simplication of this equation will yield the above gelling equation.

The effects of additions of sodium hydroxide to increase pH+ on the values of both S' and the gelling rate k become apparent. The sodium clay is more highly ionized and consists of many more and smaller particles than the acid clays, or the calcium, or magnesium clays. The gelling rate k, however, may first fall off and then rise again, for although there are more particles to gel, they will have some critical value of the pH+ at which the maximum electric charge and thick layers of water will retard the attachments.

Although there are differences of opinion concerning the nature of the forces that cause the particles to adhere,[14,15] it is clear from X-ray and chemical evidence that they are not the same at the broken bonds as the planar bonds, and also that the planar bonds may differ in polarity. Furthermore, among clays, shales and even the more uniform bentonites there are differences among the individual crystal sheets. This is the cause of wide differences in particle sizes and thicknesses. It may occur simply by having different polarity on different individual sheets of a

particle, caused by isomorphism. A particle made by stacking extremely polar sheets may deflocculate spontaneously in water, while particles made in the same way with less polar sheets require the addition of sodium hydroxide to split the planar bonds.

It is also clear that the splitting of the planar bonds may be assisted by shearing the suspension. Particles in which the individual crystal sheets are not polar enough to separate by the chemical action of water alone may do so if the suspension is stirred rapidly. This is somewhat like grinding, except that the sheets are separated at the planar bonds, and it is not necessarily associated with formation of more broken bonds. Some Texas semibentonites have this property to a marked degree.

When individual sheets in a suspension are brought together at the broken bonds, strong forces of attachment are available. The chance and thus the speed of such attachments increase with increasing temperature and with increasing number of particles, and decrease with increasing electric charges on the sheets. Sodium tannate and other chemical agents may retard the gelling rate either by increasing the electric charges as a result of adsorption of negative micelles, or by temporarily blocking the broken bonds. There is some evidence that the well-known action of the metaphosphate group is caused by a more irreversible blocking of the broken bonds and consequent reduction of the final gel strength as well as the gelling rate.

It is thus possible to impose such chemical conditions on suspensions of clay minerals that the splitting of the particles into thin sheets at the planar bonds may be either accelerated or retarded, and the gelling at the broken bonds strengthened or weakened. It is possible to impose these changes separately or simultaneously.

Applications to Drilling Problems

The importance of a thorough understanding of the surface chemistry of clays and shales is obvious to one familiar with drilling problems. It is necessary to have the colloidal clays present in drilling fluids in the proper amount and thixotropic condition. If the colloidal minerals are deficient, it may not be necessary to add them directly. It is frequently possible to adjust the chemical conditions until the flocculated minerals of the formations being drilled undergo deflocculation and thereby yield the proper amount of colloidal matter. Where this is possible, it is much more economical than the purchase of special colloidal clays.

But one of the most expensive and bewildering problems has already been mentioned; it is the opposite of the above. Some marine shales or clays encountered in drilling deflocculate so readily in the water of the drilling fluid that they accumulate rapidly. The viscosity, gel strength and gelling rate rise to intolerable values, beyond which the only recourse is to add water and replace the weighting materials. An

intelligent solution of the problem and reduction of the costs and difficulties in drilling lies only in a complete understanding of the surface chemistry of the shales involved. It has been definitely proved that it is costly to adopt the policy of letting the chemical conditions of the drilling fluids drift as they will until the difficulties have become acute, and then to treat the fluid only as the demands of the moment dictate.

This lack of planned control has frequently resulted in improvements for the time being, but at the expense of greatly aggravated conditions at the end of a few days. For example, the usual shale suspension will respond to the addition of sodium hydroxide and tannin by gelling at a lower rate and consequently degassing and settling sand more readily. The optimum pH+ for this degelling action would appear to be as high as 10, where gelling rate is low. But in this case the chemical degelling agents may act adversely on the shale cuttings and deflocculate them. Referring to the gelling equation, the gelling-rate constant k will be reduced, but the value of n_0 is increased. Under the influence of time and shearing forces, the value of n_0 may continue to rise rapidly. In effect, the "mud-making" tendency of the shale is aggravated. It is frequently found that pH+ in excess of 9 will cause a marked difference in the rate of accumulation of colloidal shales during drilling.

Some shales disintegrate and deflocculate with extreme rapidity in water even at relatively low pH+ values. They are frequently encountered in the Vicksburg and Jackson groups of the lower Oligocene and upper Eocene ages. They are characterized by weak planar binding, easy hydration and deflocculation, and their action may be modified by absorbed hydrocarbons and mechanical strains. It is necessary to resort to unusual methods to prevent their deflocculation, but the evidence is clear that they differ from other shales only in degree, not in fundamental chemical nature.

Whatever the nature of the formations being drilled, a knowledge of the colloid chemistry of the clays and shales involved will make it possible to adopt an intelligent and consistent policy of prevention rather than cure. Such a policy will consider the entire drilling program, and will make investments in chemical control that pay dividends in reduced maintenance costs, lessened delays and fewer difficulties.

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Influence of Oil Flow on Water Content

By Nico van Wingen*

(San Antonio Meeting, October, 1938)

Abstract†

Experiments performed with distilled water, unconsolidated sand and dead oil for the purpose of determining the influence of oil flow on the water content of sands were described. While results found are not necessarily, therefore, identical with those that would be obtained under natural petroleum reservoir conditions, the following conclusions were drawn.

1. When oil under constant head is flowed through an unconsolidated sand, the amount of water retained in the core is inversely proportional to the specific permeability of the core. This corroborates the view that the degree to which oil displaces water out of the pore space is limited by the size of the pores.

2. For the range investigated, the displacing action of a more viscous oil of higher specific gravity was found to be the same as a less viscous oil, or lower specific gravity.

3. The amount of interstitial water retained in the sand bears an inverse relationship to the pressure head of the displacing liquid.

4. The degree of retained water saturation of the sand appears to approach 100 per cent as the specific permeability approaches zero.

5. For the higher values of specific permeability and for the pressure range investigated the remaining amount of water in the sand occupies approximately 10 per cent of the pore space. This, together with the fact that the limiting oil velocity curve approaches approximately 10 per cent water saturation as an asymptote, indicates that beyond this point removal of water is achieved only by a stripping of the grains requiring considerable pressure drops across the sands; or by a balancing of the molecular forces.

6. As the water saturation of the sand exceeds approximately 15 per cent of the pore volume, the permeability of the sand to oil decreases rapidly.

7. Sands with water saturations as high as 40 per cent were found to produce 100 per cent oil.

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Chapter III. Petroleum Economics

A Design for More Effective Proration

By Joseph E. Pogue,* Member A.I.M.E.

(New York Meeting, February, 1939)

Over a period of years the writer has presented a number of studies[1] on various aspects of proration, in a progressive attempt to analyze critically and constructively the economic complexities of this interesting institution, which in a decade has revolutionized the economics of oil production in the United States. In the course of the investigations leading to these papers, the changing nature of proration and the principles underlying its evolution have gradually become clear, so that it is now possible to depart from the analytical method and to construct a synthesis of the steps that, if furthered by the industry, should carry proration past the economic hazards that still surround it to the goal of maximizing the value of the petroleum resource to the industry and the public alike.

Nature of Proration

Proration literally means the allocation of demand among competing producers on a pro rata basis, but the term now carries a much broader significance for it is employed to describe the entire process by which the production of crude oil in the United States is regulated. There is naturally much confusion of thought on the subject, for proration is an evolving system of control based upon principles of conservation and equity and embracing a body of practices that are tending to adjust themselves to the needs of the situation but are subjected to varying and divergent influences in the process. As it is now constituted, proration is a planned production measure designed to prevent waste, insure ratable takings, and balance supply and demand. The procedure is administered by State regulatory bodies through use of the police power of the States under authority of State conservation laws; the practice is supported by a considerable degree of voluntary conformance on the part of operators; and the Federal Government has accorded its cooperation by providing advisory quotas, circumscribing imports, checking movements of hot

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[1] References are at the end of the paper.

oil in interstate commerce, and ratifying an Interstate Oil Compact. In the course of the past 12 years, this regulatory system has become an institution with a framework of laws, court decisions, administrative bodies, committees, trade practices, and traditions.

In a limited form, proration made its appearance at various times in the past where flush production outran the absorptive powers of the market, but was abandoned in each case as soon as supply subsided so that equilibrium could be resumed without its aid. Within the past 12 years, however, the improved technical ability to find oil fields coupled with a slackening in the growth-rate of demand, has built up a productive capacity so far in excess of market requirements that proration, invoked as an emergency measure, has become a permanent establishment. There are two reasons why the conjuncture of advancing technology and maturing demand led to the institutionalization of proration: The rule of capture created an urge to produce that could not be readily restrained by the regulatory effect of price; and the tremendous difference in out-of-pocket costs between flush production and settled production transmuted this impulse into violent price changes of disturbing influence upon the economy. In consequence, once launched in the new technologic setting, proration appeared indispensable as an operating form and in turn generated the need for its spread and implementation. In short, the rule of capture became unworkable under modern technologic conditions, and proration developed as an offsetting and neutralizing influence.

Although initiated to correct conditions of overproduction, proration has its justification as a fundamental conservation measure, and its development centers around that theme. The practice of proration has clearly demonstrated that restricted flow of oil wells conserves the reservoir energy, and results in higher recoveries and lower over-the-life costs than experienced if wells are produced under conditions of open flow. The advantages of delayed production are now well understood, but these gains are not attainable under the competitive operation of leases in subdivided oil pools. Only by an actual pooling of leases in the single reservoir—unit operation—or by the imposition of rules of production that comes to the same effect—proration—can the oil pool be handled according to the dictates of advanced engineering practices. Consequently, a curtailment of flush production promotes recovery and operating efficiency while leading to improved economic balance.

Conservation

The ideal way to produce an oil field is to restrict the flow to a rate that results in the most effective utilization of the reservoir energy. In this manner the greatest practicable recovery of the oil is achieved and resort to pumping is deferred until near-exhaustion of the deposit. The form of the reservoir energy is complex, varying from pool to pool,

but in general it is represented by the driving power of edge and bottom water under hydrostatic pressure and by the compressed gas associated with the oil. The energy inherent in the gas manifests itself as a propelling force upon the release of pressure, and the dissolved gas renders the oil more fluid and reduces its tendency to stick to the sand grains. Fortunately the full effects of water drive and gas can be utilized by adjusting the flow to the most efficient, or optimum, rate, which is subject to more or less exact determination if sufficient engineering effort is devoted to the matter.

In the subdivided pool, which is the prevalent type, an additional procedure is necessary; namely, rates of withdrawal from the several properties in proportion to the available oil underlying each. This qualification is essential on two counts: first, to maintain the reservoir energy in continuing equilibrium in order to support optimum recovery; and second, to preserve equity as between the competing property owners. If the reservoir energy is not held in equilibrium but important differentials are permitted to develop in the reservoir as a result of unbalanced withdrawals, optimum recovery is unattainable and each operator must resort to the rule of capture to preserve his equity.

Conservation of oil, accordingly, can be attained by any system of operations that restrains the flow of the oil pool to the most efficient rate and enforces ratable takings among the competing operators in the pool. The determination of the optimum rate and of the ratable-takings formula is primarily an engineering problem. The objective is to deal with the reservoir energy, rather than the oil itself, but there are two schools of thought as to the best utilization of the reservoir pressure: the one regards it as a force to be spent, so much for each unit of production; the other, as a force to be conserved until virtual exhaustion of the oil. Upon further engineering research, the latter point of view will probably be found to be preferable, at least in all fields where a water drive can be utilized, for substantial pressure drops tend to induce a nonuniform encroachment of the water and, in gas-saturated pools, permit gas to come out of solution to the detriment of ultimate oil recovery.

Conservation as here defined was not attainable during the period of rapid growth in the industry, for then open-flow operations, even under the stimulus of the rule of capture, were required to meet the mounting demand. Curtailed flow, the essence of conservation, became possible only after a large potential supply of oil had been made available. Hence it was inevitable that an excess of capacity must develop before demand could be filled by production throttled down to an efficient rate. Thus in the evolution of the industry, the transition from open flow to conservation practices had to be in a setting of overproduction, or at least, potential overproduction, and proration developed as the instru-

mentality by which the physical basis for adequate conservation practices could be arrived at.

Functions of Proration

Proration has now evolved to the point where it clearly rests upon two thoroughly established principles—conservation and equity; and involves three procedures—curtailment of flow, ratable takings, and an adjustment of restricted flow to balance the measured requirements of the market. The system is administered by means of a quota system by which it is sought to bring into accord the requirements of waste prevention and market demand, without violation of the dictates of equity. In theory no pool is permitted to produce more than its market demand, it being recognized that output in excess of market demand leads to storage, physical waste, and economic instability; whereas restriction to market demand or to the most efficient rate, whichever is lower, results in effective conservation and economic advantage. It is difficult to differentiate accurately between the stabilizing effects derived from curtailment to efficient rates and those superimposed by the functioning of market-demand quotas, because any degree of restriction upon output necessitates operations under some measure of back pressure. The casual view that proration in essence is purely a stabilization measure is in error, for a substantial degree of the stabilization observable in practice is the automatic resultant of restricted flow and ratable takings instituted on the basis of conservation. It is impossible, for example, to operate an oil pool under back pressure without leveling-out the production curve and thereby flattening the cost curve; in consequence, a smoothing effect is transmitted to price. Under the practice of proration, therefore, entirely aside from the application of market-demand quotas, a significant byproduct of economic stability is inevitable.

In the operation of any economic system, of course, supply and demand must balance. Accordingly, if oil pools are to be restricted in the interest of conservation, the aggregate curtailment must conform to the dictates of demand, if consuming power is not to be regulated. Accordingly, the employment of market-demand quotas is a practical expedient to make the system workable, for existing demand does not coincide in all its ramifications with the various elements of supply at their respective optimum rates and hence an additional element of equilibration is necessary. Nevertheless the need for this additional element is probably not as great as generally believed, for judging from preliminary studies, the difference between the aggregate optimum production rate of our oil fields and market demand is not substantial; consequently proration can be directed so as to approach a plane of natural equilibrium between demand and a supply restricted according to engineering principles. At this stage, dependence upon market-demand

quotas will be greatly lessened, if not entirely removed. This conclusion deserves the greatest emphasis, for the tendency in the industry is to overlook the advanced degree of evolution and hence to miss the point of greatest significance in the economics of the petroleum industry.

Two Avenues of Change

Although proration appears to have its logical goal almost within its grasp, it is not assured that this instrumentality will be permitted to follow its natural courses to such an outcome. If the potentialities of proration were clearly envisaged by all concerned, this danger would not exist; but there are many who look upon proration solely as a stabilization device that is faulty because it fails to deliver all that is hoped of it on this score and hence desire to implement it with additional controls designed to achieve these ends. Such a course of development, in pursuit of transient and illusive gains, will lead to a condition of progressive economic regimentation that will destroy the vigor and flexibility of the industry, to the detriment of its profitability as an industrial enterprise and its serviceability to the public. On the other hand, the steps needed for the successful passage of proration into a perfected conservation measure, carrying with it a high degree of derived economic stabilization at the expense of minimum interference with competitive processes, are not complicated nor beyond reasonably early attainment.

Suggested Steps

The technique of proration is adequate for the purpose, all the necessary principles have become established, and a successful outcome waits merely upon a broader cooperation among the oil-producing states and concerted efforts on the part of the regulatory bodies, the Interstate Oil Compact Commission, and the oil operators. Five points are herewith offered for consideration:

1. The development of the optimum rate concept as a yardstick for restricting the individual oil pool.
2. The standardization of the application of bottom-hole pressure readings for the effectuation of ratable takings.
3. The harmonizing of drilling incentives with the requirements of delayed production.
4. The employment of market-demand quotas to reconcile the interim differences between optimum rates and market requirements.
5. The preservation of flexible markets to proportionate capital flow to economic requirements and prevent the development of intra-industry pressures.

Optimum-rate Concept

In its more advanced areas of application, proration has established the optimum-rate concept as a working principle, although the sig-

nificance of this accomplishment has not been fully appreciated. Experience has clearly demonstrated that the best results are obtained if the output of each pool is adjusted to its most efficient rate, and engineering technique is rapidly developing whereby this criterion can be broadly and effectively utilized. All that is needed to carry this measure to a position of perfected application is the clear perception that this principle is the *essence* of conservation and constitutes the soundest base against which to equate demand. The regulatory bodies of the several states could advantageously study this matter intensively and formulate their policies more methodically in terms of it; for the system of proration is already logically committed to the principle and its application is well under way. It may be suggested, specifically, that the Interstate Oil Compact Commission appoint an Advisory Committee of Engineers to conduct a comprehensive field investigation of rates of production in terms of recovery efficiencies with the view of designing procedures and recommending standards of practice for the signatory states.

Ratable Takings

The principle of ratable takings is well established in proration practices, but its application is not fully standardized or adequately implemented. The principle is essential to the operation of proration and should be inviolate. The art of bottom-hole pressure readings provides the technique for achieving a high degree of accurate control in the enforcement of the principle. Investigation and emphasis on the part of the regulatory bodies and the Interstate Oil Compact Commission would go far toward standardizing procedures and insuring systematic and effective application. The purchasers of crude, likewise, should invariably conform to this principle whenever resort must be had to pipe line proration, a practice only necessary, however, when market-demand quotas are faultily determined. In its administrative aspects, ratable takings involves the establishment of lease allocation keyed to pool quotas designed to achieve the best attainable balance between optimum rates and market demand.

Drilling Rates

Proration has brought about a system of delayed production divorced from the exigencies of the rule of capture, but drilling practices, while slowly adjusting themselves to the basic change in production rates, are still lagging in their conformance. It is believed that the disadvantages arising on this score are not fully appreciated, although the resulting disequilibrium may be diagnosed as the cause of much of the economic distress from which various groups in the industry are suffering. The fact is that drilling programs suitable to open-flow operations are obsolete under delayed production; but their unfitness, representing a natural lag

in a changing setting, is subject only to slow correction until accelerated by adequately enlightened attitudes.

The administrators of proration still tend to make the well the ultimate unit of proration, thus placing a premium on the drilling of unnecessary wells; whereas the proper unit is the available oil in the individual property. A change to this basis, effectuated by formulas for lease allocations involving acreage and by scientifically determined schedules for well spacing, would go far toward the correction of the existing trend toward overcapitalization of producing facilities. Effective proration requires the ability to expand the reserve without encouraging its premature development by wells in excess of market requirements. A shift in drilling incentives offers the means for harmonizing investments with delayed returns. High-cost producers dissatisfied with existing prices for crude oil would be well advised to take the lead in emphasizing the desirability of preventing the rule of capture from leading to an overinvestment in the producing department, for they are the first to suffer under such circumstances.

Market-demand Quotas

Market-demand quotas represent the most intricate phase of proration, for they involve problems of conflicting group and areal interests and introduce dangers of regimentation. The system of proration, accordingly, would do well to work toward a lessening of their incidence rather than in the direction of a growing dependence upon them. The restriction of production to market demand should properly be regarded as an interim expedient to reconcile existing differences between the most efficient production rates of oil pools and the essential requirements of the market. These differences are believed to be smaller than generally appreciated; hence progress can be rapid toward the effectuation of a system of proration based predominantly upon optimum production rates instead of market demand. Market-demand quotas, however, will continue to be helpful as an operating procedure, but their utility will diminish as engineering quotas founded upon optimum rate principles become more pervasively established and trade channels adjust themselves more completely to these measurements.

In the meantime, the market-demand quota system sequires careful administration to avoid inequities and preserve essential flexibility in the commodity flow. Quotas should be constructed by determining the demand in each pool, limited in each case to not more than the most efficient production rate; but nominations to purchase are not satisfactory evidences of demand, and careful measurements are necessary to reflect valid changes in market requirements. The regulatory bodies can exercise accounting supervision over the gathering systems of each pool and not only audit the runs but also obtain an interim check upon con-

formance to the principle of ratable takings. Once this is done and each pool is restricted to the level of buyers' real requirements, the problem of overproduction is reduced to the question as to whether the aggregate buyers' demand is a fair reflection of the needs of the ultimate consumer. The regulatory bodies, however, with local demand accurately measured for each pool, can compare their respective totals with the advisory quotas of the U. S. Bureau of Mines, adjusting if necessary their field quotas by a proportional rate in order to harmonize the totals with the requirements of equilibrium in the whole market. The advisory quotas should be based not merely upon past takings of oil but should also give reflection to the factors that determine the demands of the ultimate consumer in order that the quotas shall represent the best attainable approximations of balanced requirements.

Free and Flexible Markets

Probably no single factor has harmed our economy more than the failure to appreciate and understand the functional aspect of prices. A price is both a cause and an effect, and it is impossible to maintain a given price without that price exerting an influence upon the flow of capital—attracting capital if the price is high, repelling capital if it is low. Because of the circumstances surrounding the establishment of proration and the nature of the incentives promoting its development, it has come to be widely believed that price is the criterion by which the success of proration may be judged; indeed there was a keen sense of disappointment and frustration on the part of oil operators when the price of crude oil declined in October of 1938, after five years of steady to rising prices. Yet nothing could be further from the truth than the view that proration fails if it does not produce a continued uptrend in price. If the price gets too high, excessive amounts of capital are drawn into development and the price declines; and contrariwise, the reverse reaction is induced if price falls too low. Proration, however, can legitimately be expected to provide a smoother and more stable price structure than would be attainable under open-flow operations; but the freedom of price to move up and down and therefore to influence the elements of supply, should be conserved at all hazards.* As a matter of fact, the petroleum price

* "Market prices, worked out competitively, are the guides to the economic activities of men. They tell us what to do and what not do. . . . As an economist sees prices, their function is to tell the truth regarding what is going on in the fields of production and consumption, and to correct maladjustments and bring about a re-equilibration of the various productive activities when they get out of balance. If prices move promptly and adequately, moderate price changes will usually correct a maladjustment before it goes very far. . . . Right prices . . . are prices that move goods. . . . High or low prices . . . are not good or bad in themselves, but they are good or bad depending upon whether they reflect the facts in the situation." B. M. Anderson, Jr., Governmental Economic Planning and Prices, *The Chase Economic Bulletin* (1936) **16**, No. 1, 6, 7, 14, 15.

structure has displayed considerable elasticity during the period of proration, but at times there has been a delayed transmission of flexibility resulting in the development of internal maladjustments; an improvement in functioning would undoubtedly result if tendencies toward localized rigidities were avoided. The promotion of a free and flexible market does not necessarily mean a low or nonremunerative price; on the contrary, there is much to suggest that a sensitive market may be expected to provide a more satisfactory price level in the presence of an effective administration of proration along the lines of optimum rate production than will be possible under any phase of controls designed for purely economic objectives.

Concluding Remarks

Considering the physical, economic, and legal complications surrounding the field of oil production, it is a substantial achievement on the part of the petroleum industry to have so quickly and, relatively speaking, so successfully altered the structure of production to bring it into conformance with the technologic era. The new system is far from perfected, but the striking feature is the progress made and the vigor displayed in furthering the evolution. The suggestions advanced in this study are not novel, for the five points are well under way to accomplishment, needing merely a more concerted attitude to coordinate efforts, avoid dissipation of energy in by-paths, and prevent deflection of the natural direction of movement. Proration is not assured of a favorable outcome, for there is pressure to convert it into a pervasive economic control, but time and administrative skill can bring to sound fruition one of the most significant experiments in the economic field today.

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DISCUSSION

E. Oliver,* Ponca City, Okla. (written discussion).—Dr. Pogue has rendered valuable service both to the oil industry and to the national welfare by "constructing a synthesis of the steps that, if furthered by the industry, should carry proration past the economic hazards that still surround it." In doing that he has set out in bold relief the outline and objectives of that unique institution by which the production of crude oil and natural gas in the United States is regulated, and thus enables a more ready determination of whether it is a Frankenstein or a benign institution that the oil industry and agencies of government are building under the general term of proration.

There surely can be no division of opinion among thoughtful men that the processes of producing any limited great natural resource, confined under such physical conditions as are oil and natural gas, must be regulated in the public interest. It is then the manner and method by which proration is regulated that determine whether it will be destructive or constructive in its influence. The means determine the end.

In this paper Dr. Pogue stated certain facts that are so vital that they should be regarded as basic principles in any program designed to stabilize the oil industry. Their importance justifies direct quotation in order to avoid misinterpretation. They are:

"The rule of capture created an urge to produce that could not be readily restrained by the regulatory effect of price. . . . In short, the rule of capture became unworkable under modern technological conditions and proration developed as an offsetting and neutralizing influence. . . . Only by an actual pooling of leases in the single reservoir—unit operation—or by the imposition of rules of production that come to the same effect—proration—can the oil pool be handled according to the dictates of advanced engineering practices." Dr. Pogue also emphasized the importance of securing the most effective utilization of reservoir energy as well as of making recoverable oil and gas in the individual property the unit of proration.

My interpretation of his paper is that he frankly faces the facts that the rule of capture has become unworkable; that unit operation (or some effective equivalent) to neutralize the capture rule is necessary to enable the handling of an oil pool according to the dictates of advanced engineering practices; and that the available oil and gas in the individual property must be the legal standard of participation.

I am in thorough agreement with the simple principles enunciated by Dr. Pogue as interpreted in the immediately foregoing paragraph, but I greatly fear the steps by which they can be made effective are not as simple as his extremely thought-provoking, constructive paper implies. Evidently he abandons hope of any widespread adoption of unit operation and therefore concludes that rules of production that come to the same effect must be developed as a substitute for unit operation.

In these two conclusions he is abundantly supported by cumulative experience in the years intervening since unit operation was first advocated, but I have a very strong conviction that any expectation that proration in its present form can be developed into the equivalent of unit operation is a forlorn hope indeed. Some other means must be found to accomplish that end.

Proration of the market between pools and even between states is necessary as a permanent function of government to maintain economic stability and prevent waste through premature abandonment of high-cost producing properties during periods of prolific new discoveries. But any use of proration in the manner now exercised between properties draining from the same reservoir (except as an emergency measure until some better regulatory method can be devised) must inevitably bring down upon

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* Appraisal Engineer.

the oil industry, consuming public, and government itself evils out of all proportion to the benefits derived. These results may be summarized as follows:

1. Proration in its present form has to its credit that it has maintained a living price for oil; this in itself is a worth-while accomplishment, but its mechanics are such that:

2. It is perpetuating the high-cost production methods that have characterized the oil fields of the United States from the beginning of the industry and tends to hinder widespread application of the improved technology now available.

3. Proration built on the capture rule tends in turn to stimulate and then eliminate the independent refiners and marketers of oil, induces "hot oil" running with all its attendant evils, creates situations resulting in "Madison trials," and in general promotes inequalities, inequities, and dissension within the industry;

4. It is gradually but inevitably leading the oil industry into complete government management through government's unsuccessful attempts to correct the evils arising out of results 2 and 3 listed above, and thus is placing upon government functions that are inconsistent with its real purpose and that can be exercised more effectively by the industry itself provided sound proration methods are installed. As one government remedy after another fails in its purpose because proration is built on legal principles that conflict with physical laws, more and more regulatory legislation is demanded in the vain hope that finally the evils can be corrected by government control.

As Dr. Pogue points out, collective action among owners in a common pool is essential to conservation and stabilization of the oil industry. Two methods to attain that have been unsuccessfully attempted: (1) general adoption of unit operation; (2) proration. The first is unattainable, the second has resultant evils that make it impractical. A third typically American method of bringing about collective action among people with a common interest, which has never yet been applied to oil pools, was suggested to me by no less important authorities than the Hon. Homer Hoch, former chairman of the Kansas Corporation Commission and now Justice of the Kansas Supreme Court, and his former colleague on the Commission, the Hon. Ernest E. Blincoe. It is known as corporate power. James Bryce in "The American Commonwealth," said of this method of bringing about collective action:

"The word Democracy has been used ever since the time of Herodotus to denote that form of government in which the ruling power is legally vested, not in any particular class or classes, but in the community as a whole. This means, in communities which act by voting, that rule belongs to the majority, as no other method has been found for determining peaceably and legally what is to be deemed the will of the community which is not unanimous."

S. E. Forman, in "A Good Word for Democracy," said:

"Majority rule is resorted to because it is a practical way of getting things done. It is resorted to in a democracy not in order that 'right reason and the will of God' may prevail but in order that Government may go ahead with its business. . . . The minority acquiesces not because it is convinced that it is wrong, but because it has discovered that it is in fact a minority. With its numerical inferiority ascertained and staring it in the face it decides that acquiescence is the way of prudence and peace.

"No sensible man ever said the will of the majority makes a thing right. 'All will bear in mind,' says Jefferson, 'that though the will of the majority is in all cases to prevail, that will to be rightful must be reasonable; that the minority possesses their equal rights which equal laws must protect, and to violate which would be oppression.'

"So the minority has the right to expect that the rule of the majority will be the rule of wisdom, moderation, and justice. Democracy postulates that men at heart have a decent respect for the rights of others."

This device, or some modification of it, is used already in every other phase of American life in which collective action by many individuals is required. Familiar examples are: drainage districts, irrigation districts, school districts, villages, cities, towns, townships, counties, states, business corporations, churches, lodges, labor organizations. In fact, it is the typical American way of getting things done by large groups.

It is more flexible and a better type of collective action than is unit operation, for many reasons, among which are that it would permit each separate reservoir to have applied to it the exact degree and character of collective action best suited to the conditions of the reservoir in question. For many reasons, it is also a better type of collective action than is proration. Among these are that it would place the properties back into the hands of the owners to manage collectively in harmony with general principles laid down by the state, and turn officials of the state free to give their time and attention to activities that more properly come within the functions of government than managing private properties and determining complicated petroleum engineering problems for which they have had no training. It would enable installation of a single belt-line gathering system for the entire reservoir, to which all purchasers of crude would connect instead of connecting direct to the tank of each owner. This would not only stop stealing of oil and the running of "hot oil" but it would enable independent refiners to secure their crude on a basis somewhat comparable with the major companies and in turn would tend to eliminate any legitimate argument for separating the integrated companies into their component parts, at least in the separating of pipe lines from production. Many other benefits would arise out of bringing about collective action through corporate power than those enumerated here, but at least this will suggest some of the possibilities of that procedure.

Technology in the production of oil and gas has made wonderful strides during the past 15 years, but widespread general application of that technical knowledge to the production of oil and gas has been very slight indeed. A few isolated pools stand out as ideal operations, but proration is shot through with the concepts of oil and gas production that were prevalent 25 and 50 years ago. Its classification as a conservation measure has little basis in fact. After the discovery and chaos produced by every great new oil province discovered, beginning so long ago that the memory of man runneth not to the contrary, it has been solemnly proclaimed that never again will the lessons thereby taught be forgotten. We heard it at Oil Creek and McDonald, Pennsylvania; Lima, Ohio; Beaumont, Texas; Glenn Pool, Cushing, Seminole, Oklahoma City, East Texas—and now history threatens to repeat itself in Illinois, although the actual oil and gas deposits in that state are insignificant in volume.

Every one of these discoveries, under such enlightened control as engineering science has suggested, could have been made to produce oil and gas at a rate and in quantities that would have served as the foundation for permanent industries in its own locality for generations to come. Instead, each of them was developed under the capture rule theory, which not only sacrificed its own resources but paralyzed the oil industry elsewhere. Distant markets were sought instead of taking time to build industries near by.

It is staggering to conceive what centers of stabilized industry the states of Kansas, Oklahoma, Texas, Arkansas, Louisiana and New Mexico might have become if the capture rule had not artificially stimulated the production of oil and gas to a degree that required their immediate transportation to distant markets, where they undermined already established industries. A more statesmanlike attitude would have been to promote the use of this raw material at home. This would have necessitated the development of oil and gas pools, so that they could have been taken as needed.

On the other hand, it is difficult to comprehend how the officials of these several states propose that the next generation shall carry the tax burden this one is blithely laying upon it, while at the same time it is killing the goose that is laying the golden egg. At the present time most of the current tax income of these several states is derived from oil and gas in some form. How this tax burden can be suddenly shifted to some other source of tax income when the rapid decline in oil and gas production takes place under present methods of oil and gas exploitation is one of the problems facing early solution.

The oil industry and the State and Federal Governments in the United States have talked much but done little since better methods were first advocated. It is true there has been much scurrying around with application of skin lotions to deep-seated ills, but there has been no systematic effort to change the law of oil and gas out of which the ills complained of arise.

Dr. Pogue has stated very clearly the basic principles on which alone stability can be brought to the oil industry. They are set forth in the beginning of this discussion. To apply those principles is a most difficult undertaking. It will require, first, a very clear public understanding of the objectives and their advantages to the public, so that sympathetic cooperation may be had from it. It will then require friendly team work between the oil industry, the State Governments and the Federal Government, each doing its part fairly and openly with due recognition of the rights of all other interested people.

This is a difficult program, but the stakes are so vast and the advantages so mutually beneficial to all concerned that its accomplishment should be possible if the issues are thoroughly understood and the steps necessary to its accomplishment are clearly established. Few things will further its progress more effectively than frank, open discussion in the A.I.M.E. Petroleum Division of the issues involved.

Economic Equilibrium in Petroleum Refining Operations

By Norman D. Fitz Gerald,* Junior Member A.I.M.E.

(New York Meeting, February, 1939)

The lack of a continuous operating balance in petroleum refining, which is analyzed in this paper, is by no means a feature solely of this division of the oil industry. Serious disequilibria of a capital as well as an operating nature exist both in the producing and marketing departments, while problems in the former and to some degree the latter are complicated by political involvements. Attention has previously been directed to the unstabilizing influence of present proration formulas in stimulating unnecessary drilling.[1] While equilibrium in petroleum refining operations has been fairly well maintained in the past decade, examination of departures may prove fruitful.

Economic analysis is the application of time and motion study to the functioning of management, rather than labor. Properly applied it may reveal changes in policies that would increase the utility of the properties and facilities of the industry for stockholders, employees and the public, while contributing a stabilizing influence to the general economy. The study of economic equilibrium is essentially one of measurement and interpretation, requiring adequate data and the development of a technique of analysis that employs statistical and mathematical methods as a supplement to the broad descriptive phase of economics.

Economic equilibrium in petroleum refining is a dual concept. It embraces both the over-all balance between total storage and total demand for major products and the internal balance between the demands and inventories of the various products. The latter is the more complex of the two for it is concerned with proportionating the supplies of the several products stemming from the joint source to the demands for the individual products which are subject to wide variations. All the products are essentially nondurable goods, and they are used both by producers and consumers but in varying proportions. Motor fuel is very largely a consumer's good, while residual fuel oil is almost entirely a producer's good, the other products falling between these extremes. The peculiar-

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[1] J. E. Pogue: Economic Aspects of Drilling. Amer. Assn. Petr. Geol. (March 16, 1938).

ities of each are reflected in the contrasting responses of supply and demand to changes in prices and industrial conditions; some are elastic and sensitive, while others are inelastic and stable.

The general uptrend in the total demand for petroleum products during the past decade has been marked by considerable differentiation between the several components. The constituent demands have changed continuously in relation one to another, under the influence not only of trend considerations but of seasonal, cyclical, and random factors. While the proportion of gasoline demand has remained relatively constant, the percentage of gas and distillate oil demand has expanded at the expense of residual fuel oil. Supplies are equated to these demands through the mechanisms of prices and inventories, with price performing a dual function. Price acts both as a cause and as an effect, for a rising price normally increases supply and constricts demand, although these economic effects are often obscured by the more powerful influence of industrial activity, as well as by the quick response of supply and the slow response of demand to changes in price. Inventory variations should permit adjustments between supply and demand arising from transient factors without recourse to changes in current supply or price. In the long run, however, dynamic equilibrium is maintained and the supplies of the various products are adjusted by the relationships between economic utilization and basic cost.

The purpose of these analyses is to determine the factors motivating short-run departures from over-all balance and balanced relationships between the products in petroleum refining, in the hope that better understanding might lead to minimizing them.

Data and Methods Employed

The study covers the period January 1930 through September 1938; prior data were not available. It is limited to the area east of California because in many respects the petroleum economy of California is different from that of the remainder of the country, as manifest in its unusual dependence on exports, its classification of some crude oils with fuel, its partial isolation due to high transportation charges, and the absence of strict proration.

Statistics of current supply, current demand, and total inventories of gasoline, gas and distillate oil, and residual fuel oil were obtained from the reports of the U. S. Bureau of Mines. Totals of each of these items for the three products were computed and used in conjunction with the Federal Reserve Index of Industrial Production from the *Survey of Current Business* in measuring the over-all balance. Prices for each of the products at Mid-Continent refineries were obtained from the *Oil Price Handbook* and the *National Petroleum News*.

The over-all supply and demand relationship is measured by the conformity of the total supply and total demand for the three products. Inasmuch as supply and demand actually are in fairly close harmony, the problem can be simplified by comparing demand with the cumulation of small excesses or deficits of supply expressed as inventories. As an additional aid to a better understanding of certain relationships demand has been correlated with industrial production, and industrial production with inventories.

The methods used in determining both the over-all and the internal equilibria are those of correlation analysis. For the economist, this branch of statistical technique is simply the rough equivalent of controlled

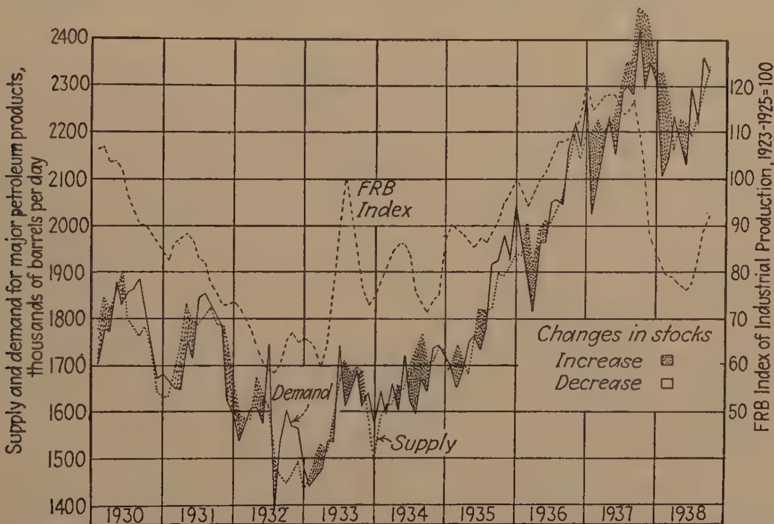

FIG. 1.—SUPPLY AND DEMAND FOR MAJOR PETROLEUM PRODUCTS EAST OF CALIFORNIA, AND FRB INDEX OF INDUSTRIAL PRODUCTION.

experiment, whereby the relationships between variables may be developed from masses of random observations. Coefficients of correlation are pure numbers indicating the degree of similarity between series. They are useful for comparative purposes in evaluating the period by which one series lags behind another. Furthermore, the equations developed from them permit estimation of a dependent variable from one or more independent variables by selection of the best weights.

Over-all Equilibrium

There is a persistent lag of from three to six months in the conformity of the total demand for petroleum products with industrial production. The total demand, total supply, excesses or deficits of supply, and the Federal Reesrve Board Index of Industrial Production are shown in Fig. 1. The degree of concurrence between the total demand and the industrial

production series in peaks, troughs, and swings, confirms the fact that petroleum demand is closely linked with general trade, although there is an appreciable difference in their trends. In Table 1, the lag of demand behind business is shown by comparison of correlation coefficients. The tendency of petroleum demand to follow business activity is consistent in both halves of the period. While the average lag for the period as a whole is about three months, maximum correlation occurs at three

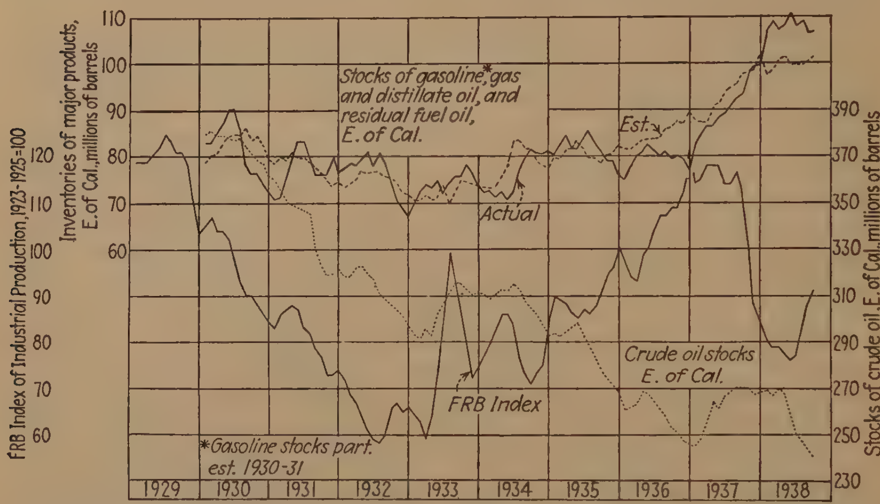

FIG. 2.—INVENTORIES OF MAJOR PETROLEUM PRODUCTS EAST OF CALIFORNIA AND ESTIMATES FROM RELATED STATISTICAL SERIES: STOCKS OF CRUDE OIL EAST OF CALIFORNIA, AND FRB INDEX OF INDUSTRIAL PRODUCTION.

months' lag in the first half of the interval and at six months' lag in the second.

TABLE 1.—*Determination of the Lag in Conformity of Petroleum Demand with the FRB Index of Industrial Production*

Months of Lag	Coefficients of Correlation		
	January 1930 to April 1934	May 1934 to September 1938	Full Period
0	+0.68	+0.48	+0.66
3	+0.80[a]	+0.56	+0.70[a]
6	+0.66	+0.72[a]	+0.65

[a] Best correlation.

There is a persistent lag of from 12 *to* 15 *months in the conformity of inventories of petroleum products with industrial production.* Inventories of petroleum products, the cumulation of small excesses and deficits of supply, and the FRB index are shown in Fig. 2. These series indicate a

definite tendency for movements of inventories to follow changes in the index of industrial production by more than 12 months. This is strikingly shown by the substantial increase in the storage of products during 1937 and the first half of 1938, whereas industrial production reached a peak in December 1936, and demand for products attained its high point in September 1937. In other words, the oil industry did not reduce its operations sufficiently to commence liquidation of its excessive inventories of products until more than 17 months had elapsed from the top in industrial activity. The data in Table 2 show a maximum coefficient of correlation for a 12 months lag of inventories behind industrial production. Separate analyses for the first and second halves of the period

TABLE 2.—*Determination of Lag in Conformity of Inventories of Petroleum Products with FRB Index of Industrial Production*

Months of Lag	Coefficients of Correlation		
	January 1930 to April 1934	May 1934 to September 1938	Full Period
0	+0.46	−0.26	+0.21
3	+0.62	−0.04	+0.34
6	+0.57	+0.36	+0.48
9	+0.62	+0.65	+0.52
12	+0.65[a]	+0.82	+0.68[a]
15	+0.53	+0.90[a]	+0.59

[a] Best correlation.

indicate lags of 12 and 15 months, respectively, suggesting that the tendency is consistent. Inventories, instead of reflecting current business conditions, are a full year behind, thus accentuating swings in the petroleum economy.

Many factors play a part in determining the inventories of refined products; such as petroleum demand, crude-oil stocks, and the level of industrial production. The similarities of fluctuations in these factors and in products inventories despite lags and divergences in trends are shown in Figs. 1 and 2. The same impulses that result in changes in the storage of refined products may affect the stocks of crude oil, while shifts in the storage of crude oil resulting from expediencies in the production departments, particularly of integrated companies, may easily be carried through to the refining divisions and affect inventories of products. In any case similarities of movement in the components of the total petroleum inventories appear logical. The available data suggest that the particular factors presented in Table 3 are most closely related to the inventories of petroleum products Coefficients of correlation have been

computed both before and after coincidence of trends have been obtained by the introduction of a trend element as an independent variable.

TABLE 3.—*Relationships of Inventories of Petroleum Products with Various Factors*

	Coefficients of Correlation, Jan. 1930 to Sept. 1938	
	Before Trend Adjustment	After Trend Adjustment
A Petroleum demand, 12th preceding month	+0.7774	+0.9970
B Crude-oil stocks, currently	−0.3755	+0.9965
C FRB index of industrial production, 12th preceding month	+0.6775	+0.9932
All factors		+0.9983

Therefore it appears that inventories of petroleum products of any particular month reflect the influences of total demand of the twelfth preceding month, the level of industrial production of the twelfth preceding month, and the current volume of crude oil in storage. The following equation has been derived from these data and the trend element to represent their relationships to the inventories of refined products.

Inventories of Refined Products[a]

Products Storage, MB	Demand, TBD	Crude Storage, MB	FRB Index, '23–'25 = 100	Trend Element, Jan. '30 = 1
X	= 0.0124*A*	+0.1000*B*	+0.1744*C*	+0.2616*D*

[a] MB, millions of barrels; TBD, thousands of barrels per day; *D*, increases by 1 each month.

Estimates of the volume of petroleum products in storage as derived from this equation are shown in Fig. 2, in conjunction with the actual data. The degree of conformity of these series is such as to establish the probability that the factors employed in the analysis are of major importance and that the influence of preceding demand and industrial conditions, rather than those of the near future, are paramount considerations.

It should not be assumed that sound forecasts can be made from this formula or that it will come even moderately close to defining future inventory movements, for it is based upon cumulative errors rather than upon normal responses. Such maladjustments in inventory policy will eventually be corrected more rapidly as the difficulties and the means of avoidance become more widely understood. While this pattern may be repeated, it should become of less consequence in the future, and the period required for equilibrium to be restored should be foreshortened.

Internal Equilibrium

The examination of internal equilibrium, or the balance between the products, is expedited by the elimination of certain influences common to each of a group of factors and therefore not germane to the analysis: such as trends, swings in business, and shifts in the price level. Each factor of supply, demand, inventory and price is expressed as a percentage of the current monthly average of that factor for each of the three products; average seasonal variations are removed; and mean values adjusted to

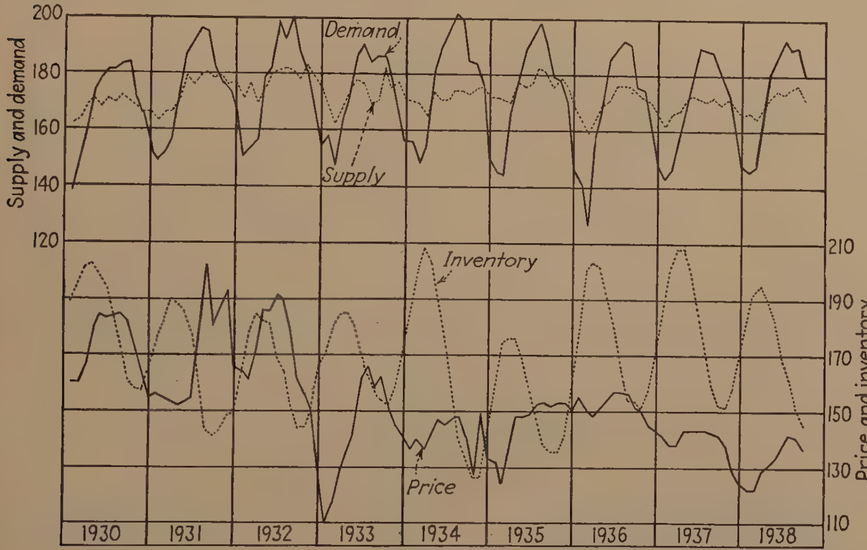

Fig. 3.—Gasoline supply, demand, price, and inventory east of California, in relative units uncorrected for seasonals.

equal 100. For example, the calculations of the current supplies of the products east of California for January 1930, in relative units were as follows:

Product	Relative Units				
	Million Barrels	Percentage of Average	Average for Januaries	Adjustment for Seasonal	Adjusted to 100
Gasoline	29.721	163	168	− 5	95
Gas and distillate oil	5.147	28	37	− 9	91
Residual fuel oil	19.925	109	95	+14	114
Total	54.793	300	300	0	300
Average	18.264	100	100	0	100

In this way all the data are expressed in strictly comparable terms. The true relationships are unaltered and are more accurately and simply

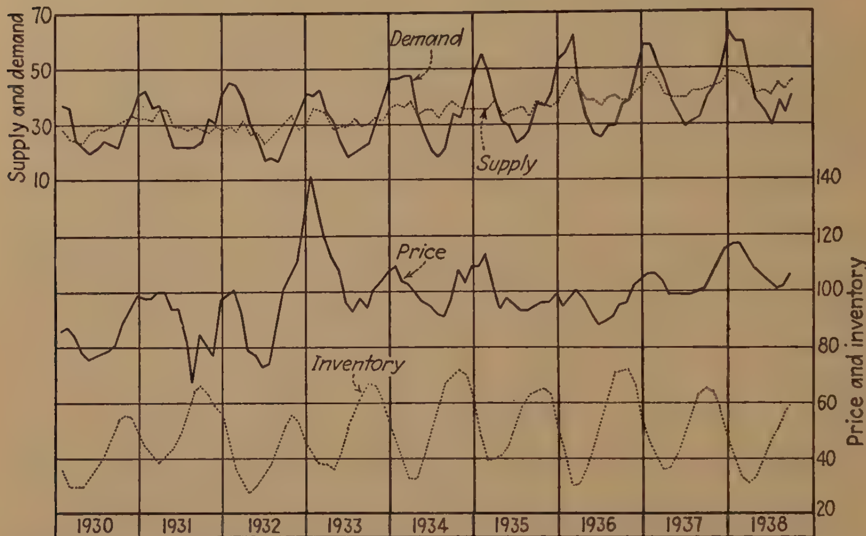

FIG. 4.—GAS AND DISTILLATE, OIL SUPPLY, DEMAND, PRICE, AND INVENTORY EAST OF CALIFORNIA, IN RELATIVE UNITS UNCORRECTED FOR SEASONALS.

perceived by thus minimizing the disturbances to which each of the group of items is subject. This entire phase of the analysis is confined solely to these relative units; the data for gasoline, gas and distillate oil, and resid-

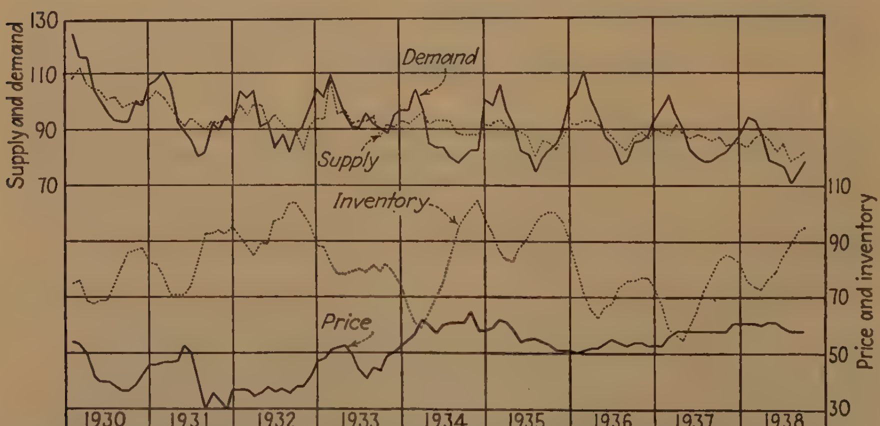

FIG. 5.—RESIDUAL FUEL OIL SUPPLY, DEMAND, PRICE, AND INVENTORY EAST OF CALIFORNIA, IN RELATIVE UNITS UNCORRECTED FOR SEASONALS.

ual fuel oil, uncorrected for seasonal, are shown graphically in Figs. 3 to 5, respectively and the seasonal averages are tabulated in Table 4.

TABLE 4.—*Averages of Relative Units Used for Seasonal Adjustments*

Month	Gasoline				Gas and Distillate Oil				Residual Fuel Oil			
	Supply	Demand	Price	Stocks	Supply	Demand	Price	Stocks	Supply	Demand	Price	Stocks
Jan.	168	148	142	176	37	49	107	43	95	103	51	80
Feb.	167	147	141	189	36	47	106	36	97	106	53	75
Mar.	168	160	145	194	36	39	102	34	96	101	53	71
Apr.	173	177	152	193	33	32	96	35	94	92	52	72
May	176	186	154	186	33	26	94	40	91	88	52	75
June	176	192	158	175	33	23	91	47	91	85	51	78
July	177	193	162	164	34	25	89	53	89	83	49	83
Aug.	177	193	162	152	34	25	90	60	89	82	48	89
Sept.	176	183	156	146	36	31	95	63	89	86	49	90
Oct.	176	178	154	145	35	34	98	64	89	88	48	91
Nov.	175	169	152	150	35	39	100	61	91	92	48	90
Dec.	171	154	143	162	36	49	107	52	93	98	51	86

TABLE 5.—*Equations for Supply of Each Product, All Items in Relative Units*[a]

	Supply		Demand	Price	Inventory
GASOLINE SUPPLY					
Jan. 1930–April 1934	X	=	$0.855A$	$+ 0.050B$	$+ 0.095C$
May 1934–Sept. 1938	X	=	$0.748A$	$+ 0.227B$	$+ 0.025C$
Full period	X	=	$0.843A$	$+ 0.074B$	$+ 0.083C$
GAS AND DISTILLATE OIL SUPPLY					
Jan. 1930–April 1934	X	=	$0.727A$	$+ 0.106B$	$+ 0.167C$
May 1934–Sept. 1938	X	=	$0.826A$	$+ 0.084B$	$+ 0.090C$
Full period	X	=	$0.796A$	$+ 0.105B$	$+ 0.099C$
RESIDUAL FUEL OIL SUPPLY					
Jan. 1930–April 1934	X	=	$0.770A$	$+ 0.110B$	$+ 0.120C$
May 1934–Sept. 1938	X	=	$0.679A$	$+ 0.321B$	$+ 0.000C$
Full period	X	=	$0.858A$	$+ 0.056B$	$+ 0.086C$

[a] X, Estimate of current supply; A, current demand; B, current price; C, current inventory.

The rate of supply of each product reflects the influences of demand, price, and inventory. Each factor was used currently and its weighting obtained by the methods of multiple correlation. In this way the net effect of each factor on the immediate functional responses of supply may be determined simultaneously. Separate analyses are made for the two halves of the interval and the period as a whole. The equations derived are shown in Table 5.

The relative rates of supply of each of these products and estimates derived from the full-period equations are shown in Fig. 6. The degree of conformity appears rather good for each product, but if higher correlation

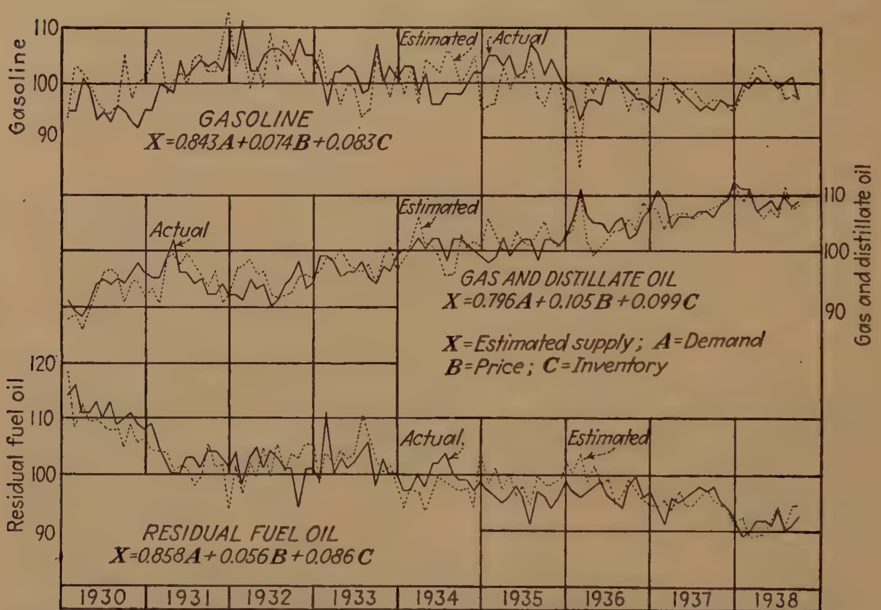

FIG. 6.—RELATIVE RATES OF SUPPLY FOR EACH PRODUCT AND ESTIMATES FROM DEMAND, PRICE, AND INVENTORY: ALL FACTORS CORRECTED FOR AVERAGE SEASONAL.

rather than determination of normal quick responses were the objective, prior demands would have been introduced as additional factors and nonlinear functions employed where indicated. Demand and price each plays a part in furthering supply, but the very presence of high inventories tends to stimulate supply without respect to demand or price. This influence, which appears in every equation for each product, and doubtless results from the momentum of supply derived from preceding demand and price stimuli is the surprising feature shown in the relationships.

The importance of each factor in contributing to variations in relative supply may be evaluated directly, and analysis extended to shifts in time and comparisons between products. Homogeneity of units in all the series and identical mean values make this possible. The average weight

of each of the supply-determining elements is shown in Table 6 by products. Demand accounts for 83.3 per cent on the average, price 7.8 per cent, and 8.9 per cent to momentum associated with inventories. The range of variation in the importance of each item between the products is rather narrow.

Inventories of each product exert a positive influence upon the rate of supply instead of exerting a negative or normalizing tendency. Therefore, price is required to fulfill not only its conventional economic functions but also that of overcoming the tendency of inventories to induce additional supplies. The preceding courses of demand and price apparently have a persistent influence upon supply. This tendency counterbalances and reverses any response to the conventional function of inventories upon

TABLE 6.—*Average Importance of Factors Determining Relative Rates of Supply of Each Product*

Product	Percentage of Total Motivation			
	Demand	Price	Inventory	Total
Gasoline	84.3	7.4	8.3	100.0
Gas and distillate oil	79.6	10.5	9.9	100.0
Residual fuel oil	85.8	5.6	8.6	100.0
Average	83.3	7.8	8.9	100.0

supply. Therefore, the momentum developed in this way appears in all of the equations of supply as an unstabilizing tendency associated with storage. While it is natural and proper to increase total inventories with an expansion in aggregate shipments, when the influence of both demand and price have been accounted for simultaneously, the residual tendency should be toward a reduction in supply when the inventory is large, and vice versa. This is especially true in the internal balance, for inflation of one inventory is relative to the others and has its counterpart in the automatic deflation of another. This lack of equilibration through the influence of inventories throws an excessive burden upon price in effectuating a balance between supply and demand. Consequently unnecessarily wide swings are induced in the supply, price, and inventory relationships of the several products.

The joint nature of the supply of petroleum products causes any abnormalities in the supply-inducing factors to be transmitted from one product to another, rather than be counteracted. An insight into the possible nature and origin of some of the disturbances to internal balance may be inferred from simultaneous consideration of the full-period equations of supply for the three products:

Summary of Products Relationships

Product	Supply		Demand		Price		Inventory
Gasoline	X	=	$0.843A$	+	$0.074B$	+	$0.083C$
Gas and distillate oil	X	=	$0.796A$	+	$0.105B$	+	$0.099C$
Residual fuel oil	X	=	$0.858A$	+	$0.056B$	+	$0.086C$
Average	X	=	$0.833A$	+	$0.078B$	+	$0.089C$

The links between these equations are fixed by the premises of internal equilibrium as manifest in the method of analysis which has established the sums of the supply, demand, price, and inventory factors for the three products for any month each equal to 300. Therefore, distortions due to abnormalities of demand or price of one product are not absorbed in part by the theoretically normalizing balance wheel of inventories but are transmitted to other products. Supply may be stimulated, but lacking demand the excess is carried to inventory, and the momentum associated with storage further complicates the problem. Meanwhile the corresponding elements of other products are distorted in the opposite direction, inhibiting supply and requisitioning the excess of demand from inventory. In this way a price out of line with demand may alter the supply of a particular product and induce unsound shifts in the inventories of the various products. Eventually the correction of the maladjustments, including dissipating or reversing the momentum associated with inventory, must be effectuated entirely through the functioning of price. These characteristics make for swings in supply, demand, price, and inventory items, which are much greater than is necessary or desirable. Such imperfections of economic balance are not only unfortunate for the industry as a whole, but their influence spreads further, tending to induce and accentuate swings in the general economy.

Recent shifts in the importance of the supply-inducing factors have been favorable in character. The nature and extent of these changes for each product and the total have been determined by differences in the coefficients of the component stimuli in the equations of supply taken from Table 5, for the first and the last halves of the interval; these variations are shown in Table 7. The total motivation of demand has declined slightly and there has been a moderate drop in the momentum associated with inventories while these changes have been counterbalanced by a substantial rise in the part played by the functioning of price. Although the ascendancy of price is not necessarily sound, the decline in the disequilibrating momentum associated with the inventories of each of the three products is an encouraging development. This impetus to store a product when the demand has decreased and, conversely, to withdraw from storage when the demand has increased, rather than

TABLE 7.—*Net Changes in Motivation of Relative Rates of Supply of Each Product from First to Second Half of Period*

Product	Net Change in Percentage			
	Demand	Price Net Change	Inventory in Percentage	Total
Gasoline	−10.7	+17.7	− 7.0	0.0
Gas and distillate oil	+ 9.9	− 2.2	− 7.7	0.0
Residual fuel oil	− 9.1	+21.1	−12.0	0.0
Total	− 9.9	+36.6	−26.7	0.0

shift yields between products to maintain internal balance, has been a source of trouble to the industry by accentuating the departures from conditions of equipoise. Gasoline and residual fuel-oil supplies have both become more responsive to price, while the effects of demand and inventory momentum are slightly less. The supply of gas and distillate oil has become more sensitive to demand and less subject to price and inventory momentum. This change is indicative of the increasing willingness of refiners to adjust operations to produce more gas and distillate oil without the added incentive of a higher price.

Suggestions for Maintenance of Equilibrium

Despite the fact that the oil industry has one of the best and most complete statistical registers among our major industries, it appears to give little attention to the management of inventories of products until the problem becomes acute and important price changes have been induced. This difficulty could be mitigated if the current supply of products were adjusted to the near future level of demand, rather than to shipments of the recent past. Then the lag in the adjustment of inventories to demand would be reduced and swings in prices minimized by the maintenance of a better over-all balance. Experience in the petroleum industry, in common with most industries, has shown that inventories of products are generally accumulated at rising or high prices and liquidated at declining or low prices, accentuating the swings in prices. Speculation in petroleum inventories has imposed a heavy cost upon the industry because it is so difficult to effect reductions, and the influence of small excesses in storage is important in determining the prices of very large volumes of products currently produced and sold. Even the burdensome increase of 29.9 per cent in the storage of refined products in 1937 represented only 2.8 per cent of the total shipments for the year. During the early stages of a decline in business, a portion of demand should be met from inventory, thus freeing working capital and hastening the return to stability.

An unusual opportunity is afforded in anticipating changes in requirements because shipments of petroleum products appear to lag industrial production by more than three months. Seasonal shipments induce wide movements in the storage of particular products, but the complementary nature of their requirements permits efficient operation with a relatively constant over-all inventory. An effort should be made to counteract the present tendency of excessive supplies to be produced for several months after a decrease in demand with its resulting inventory increases. Care should also be exercised to avoid an expansion of inventories based upon abnormal or erratic demands as contrasted with wise increases based upon stable advances in shipments.

The problem of balancing the supplies and demands of the various products is not always a simple one, especially for the individual refiner. Limitations imposed by refinery equipment, the characteristics of the available supply of crude oil and the quality requirements for the finished products often make major shifts in yields impractical or impossible. It is essential therefore that changes in the relationships of the demands for the several products be reflected in supplies as quickly as possible, if they cannot be anticipated. For the sooner the necessary adjustments are made, the smaller they would have to be to balance supplies with demands and minimize the pressures upon the price structure.

Having allowed for normal seasonal considerations, the rates of near future demand for each product, with due weight given to the level of inventories, should govern the rates of supply. In this way, internal balance would be maintained, the possibility of overrefining particularly to yield one product would be obviated, and the necessary storage of all products minimized. Caution should be exercised to recognize unstable relationships between the rates of supply for the various products, which frequently originate in the momentum developed by preceding demand and prices or by abnormal levels of price in relation to demand. Yields of the several products should be distributed on the basis of relative demands lest the abnormalities in economic relationships of one product be translated into distortion in another. The principles of economic conduct here outlined would in no wise restrict the free interplay of economic forces, because changes in price levels and price relationships would be unimpeded. However, the narrower equilibrium range that would result between the supplies of the various products and their demands would tend to limit price fluctuations, decrease the speculative hazards of the industry and produce an evener flow of profits, wages, taxes, and capital requirements; exerting a smoothing effect upon the general economy.

In Conclusion

The economic problems of the oil industry have grown rapidly in recent years and now appear of similar magnitude to the engineering

problems that characterized an earlier phase of its growth. The need for economic skill in corporate control has been increased by the instability of our present economy. Although there is an active interest in the statistics of the oil industry, it is largely academic and falls far short of being reflected in economic action. In all probability, however, the economic functions of management eventually will be developed on a basis comparable with the knowledge and skill at present existing in other technical fields. An interesting contrast can be drawn between engineering development and current economic research in the oil business. The industry is in full control of its technical expansion and understands its physical problems far better than others; today, however, a major part of the economic research into the character and functioning of the petroleum and other industries is being conducted under the sponsorship of government and outside the control of industry. The potential implications of the extensive and often advanced nature of the economic analyses carried on beyond the purview of management should receive the attention warranted by such a state of affairs.

DISCUSSION

(*Sidney A. Swensrud presiding*)

V. S. Myers,* New York, N. Y. (written discussion).—Aside from the practical aspects of this paper, and speaking broadly, the paper is particularly significant because it is a commendable attempt to direct the attention of management in the petroleum industry to a type of economic analysis that holds high potential possibilities for increased efficiency in management and increased profits. Dynamic analysis is the basis of successful operation in many outstanding fields of industrial and business endeavor today. The petroleum industry stands to benefit exceedingly when it discovers and applies the principles of dynamic economic analysis to its copious statistics. From the dais the author of this paper extemporaneously remarked in substance that it requires no particular skill for management to show earnings while the industry is enjoying its period of growth and the yearly increment of demand increase is effective in wiping out both prior and current operating discrepancies.

Management would be prudent to anticipate the time when demand will level off and the struggle for existence force it to adjust its policies to its new environment. The transition from the type of management applicable to a growing industry to that applicable to one whose growth rate has tapered off will be greatly facilitated if present management will take a more realistic point of view in its practical economics. There is no reason to believe that any or all individual units of the petroleum industry could not approach the enviable record of management and profit that has been set by the industries that already are applying scientific economic statistical methods. This paper by Dr. Fitz Gerald indirectly pioneers such an idea.

Static analysis, which is the current vogue in dealing with petroleum economic statistics, is satisfactory within certain limits. A cross-sectional statistical picture or description of an economic situation occurring at a certain time is interesting in itself, but the kaleidoscopic character of our economy rarely renders the elements in any two practical situations (selected at random) such as those with which management must

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deal so that they will coincide. It is obvious that the value of static analysis is seriously restricted. It is only when a consecutive series of these static, statistically portrayed economic situation pictures are combined into a smooth succession of progressing economic pictures that the important dynamic relationships existing between the individual economic elements are revealed as in bas-relief and the foundation for rational economic forecasting is laid. (An analogy suited to the difference between static and dynamic analysis is that of the difference between the mechanics of stereopticon and moving pictures; the latter being infinitely more effective for exhibition and analysis.)

Trend analysis and trend extrapolation, which are the current vogue for prediction in practical petroleum economic statistics, give unreliable results since time in itself, although it may provide a convenient statistical factor, is certainly no economic element. In other words, the mere fact that the secular trend of past experience has progressed in a given direction is no assurance that it is to continue in that direction. The growth or decline of any economic element is not due to time but is due to its normal relationship with other economic elements interoperating with it. This leads to a consideration of two types of correlation analysis. The first type is represented by a plot of two or more economic elements in which time is used as one coordinate, usually the abscissa or horizontal axis. Correlation is measured by scansion of the shapes of the two secular plots and is necessarily qualitative, a change in direction, leading, lagging or coinciding with and suggesting a change in direction of the other. If petroleum industry management is to make efficient use of economic statistics it must not only know the direction but the amount of continuance of change that is predicted for the economic element of its particular interest, and if management is to be expected to have any lasting confidence in these qualitative results, they must be accompanied by an index of their reliability. These latter two concepts are most expediently visualized by a plot on which both coordinates are economic elements. In such a plot, time is not ignored, but is represented as the point of coincidence of two economic elements. This type of plot is known as a "scatter diagram." The "best fit" to the plotted points yields the quantity of change to be expected; the dispersion of the plotted points about this line indicates the reliability of the estimate.

The excellence of this paper by Dr. Fitz Gerald is partly due to the infallibility of his method of analysis as a producer of significant results and to his frankness in supplying indices of reliability. (The latter, by the way, are conspicuously absent in present-day estimates on petroleum statistics.) I would like to call attention to the fact that although scientific methods offer tremendous possibilities for the improvement of management in the petroleum industry, and the increase in its profits, they are being neglected. In connection with the petroleum industry, consequently, scientific statistical methods are suffering the growing pains of immature development. Nevertheless, the result of any attempt at dynamic analysis, even though in the stage of engineering research, is far and away ahead of the results of analysis by other analytical methods, just as the early motion pictures, imperfect as they were, were far ahead of the "stills."

World Consumption of Petroleum and Related Fuels during 1938

By V. R. Garfias,* R. V. Whetsel,* Members, and J. W. Ristori,* Associate Member A.I.M.E.

(New York Meeting, February, 1939)

Preliminary estimates indicate that world consumption of petroleum and related fuels in 1938 will be close to 1,908,000,000 bbl., or approximately 7,000,000 bbl. less than in 1937. This total does not include military consumption in foreign countries, which for obvious reasons is not made public. Foreign military consumption in any one year, however, is approximately represented by the difference between the total *production* of petroleum and related fuels and the "partial total" consumption above noted, after adding any decrease, or subtracting any increase in stocks in the United States. Fig. 1 illustrates this "difference" and shows that in 1937 and 1938, owing to the wars in China and Spain and the possibility of armed conflict in Central Europe, foreign military consumption—and possibly additions to foreign stocks—increased nearly 70,000,000 bbl. in 1937 over 1936 and remained at this high rate throughout 1938.

No official information on foreign oil stocks is available to the writers. Table 1, recently published, purports to give the oil in storage in some of the European countries, but it is not known whether the figures include oil stocks for military purposes.

Table 1.—*Oil Stocks in Various Countries*[a]

Country	Jan. 1, 1937	Jan. 1, 1938	Country	Jan. 1, 1937	Jan. 1, 1938
Russia	69,236,000	72,055,000	Netherlands	2,649,000	3,492,000
France	18,443,000	19,773,000	Sweden	1,424,000	1,909,000
Germany	10,573,000	10,390,000	Hungary	1,103,000	1,391,000
Rumania	9,233,000	6,996,000	Austria	991,000	978,000
Italy	6,503,000	5,047,000	Switzerland	384,000	384,000
				120,539,000	122,415,000

[a] *New York Times*, Sept. 18, 1938.

It should be noted that with the annexation by Germany of Austria and part of Czechoslovakia the consumption of the country has increased to 53,000,000 bbl., which is about 36,000,000 short of the German produc-

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TABLE 2.—*World Production and Consumption of Crude Oil, Petroleum and Related Fuels*

THOUSANDS OF BARRELS

Year	Production of Crude Oil and Related Fuels	Consumption of Petroleum and Related Fuels	Excess Production over Consumption			United States		Military Consumption and Storage Outside U.S.A.
			United States	Outside United States	World Total	Excess Exports over Imports	To Storage	
1932	1,362,039	1,348,407	R13,011	26,643	13,632	28,781	R41,792	55,424
1933	1,467,128	1,406,923	67,427	R7,222	60,205	60,254	7,173	53,032
1934	1,562,834	1,507,599	26,164	29,071	55,235	64,013	R37,849	93,084
1935	1,702,793	1,614,475	53,027	35,291	88,318	75,474	R22,447	110,765
1936	1,864,997	1,795,560	52,209	17,228	69,437	74,890	R22,685	92,122
1937	2,121,337	1,914,856	161,445	45,036	206,481	115,677	45,768	160,713
1938	2,062,090	1,907,507	130,770	23,813	154,583	139,000	R8,230	162,813

TABLE 3.—*World Production of Crude Oil and Related Fuels*

THOUSANDS OF BARRELS

Country	1937			1938		
	Crude Oil	Related Fuels	Total	Crude Oil	Related Fuels	Total
United States	1,279,160	51,967	1,331,127	1,212,970	52,000	1,264,970
Russia	200,000	1,000	201,000	209,000	1,000	210,000
Venezuela	185,700	900	186,600	189,100	900	190,000
Iran	78,740	1,000	79,740	75,000	1,000	76,000
Netherlands East Indies	56,270	1,900	58,170	55,600	2,000	57,600
Rumania	52,180	800	52,980	48,500	700	49,200
Mexico	46,900	900	47,800	37,000	1,000	38,000
Iraq	30,600		30,600	30,900		30,900
Colombia	20,290	600	20,890	21,500	600	22,100
Trinidad	15,500	120	15,620	17,800	200	18,000
Germany	3,180	12,140	15,320	4,300	13,000	17,300
Peru	17,470	1,300	18,770	16,000	1,200	17,200
Argentina	16,240	400	16,640	16,300	400	16,700
British India	9,850	140	9,990	9,860	140	10,000
Bahrein Islands	7,760		7,760	8,480		8,480
Canada	1,180	1,800	2,980	5,000	3,000	8,000
British Borneo	6,030	130	6,160	7,180	150	7,330
Poland	3,710	150	3,860	3,820	150	3,970
Japan	2,490	150	2,640	2,530	150	2,680
Ecuador	2,160		2,160	2,260		2,260
Egypt	1,150	50	1,200	1,540	60	1,600
Others	1,830	7,500	9,330	2,100	7,700	9,800
	2,038,390	82,947	2,121,337	1,976,740	85,350	2,062,090

TABLE 4.—*World Consumption of Petroleum and Related Fuels*[a]

THOUSANDS OF BARRELS

Country	1937						1938					
	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total
United States	519,352	54,972	442,355	23,323	129,680	1,169,682	521,000	56,000	407,000	21,200	129,000	1,134,200
Russia	24,000	41,000	64,000	9,200	20,000	158,200	27,000	42,000	65,000	9,500	21,000	164,500
United Kingdom	44,000	6,700	27,400	3,500	4,300	85,900	47,500	7,000	30,000	3,800	4,500	92,800
France	25,000	1,700	17,200	2,300	4,700	50,900	26,500	1,800	18,300	2,500	4,900	54,000
Germany	23,500	800	13,000	3,000	5,000	45,300	27,300	1,500	15,500	3,500	5,200	53,000
Canada	21,000	600	14,000	3,600	4,300	43,500	23,000	650	15,500	4,000	4,850	48,000
Argentina	6,300	1,200	16,000	300	1,500	25,300	7,000	1,300	17,000	400	1,800	27,500
Japan	10,400	2,000	16,500	2,500	2,700	34,100	7,800	1,500	11,800	1,800	2,100	25,000
Netherlands West Indies	180	30	13,500	40	4,300	18,050	250	50	17,000	50	5,000	22,350
Italy	5,200	900	11,300	900	1,700	20,000	5,500	950	11,850	950	1,750	21,000
Mexico	3,600	1,000	15,000	300	1,690	21,590	3,000	800	12,600	200	1,400	18,000
British India	2,650	6,950	4,100	1,050	1,400	16,150	2,700	7,000	4,100	1,050	1,400	16,250
Australia	7,500	1,300	3,600	450	1,000	13,850	7,800	1,300	3,800	450	1,100	14,450
Rumania	900	1,050	9,000	170	1,500	12,620	1,000	1,200	10,000	220	1,800	14,220
Netherlands East Indies	1,500	1,950	6,100	250	1,500	11,300	1,500	2,000	6,100	250	1,500	11,350
Netherlands	3,500	2,000	3,500	400	1,000	10,400	3,600	2,000	3,800	450	1,100	10,950
Iran	600	1,200	5,500	350	2,500	10,150	600	1,300	5,700	400	2,600	10,600
Sweden	4,000	900	2,900	400	700	8,900	4,100	900	3,000	400	700	9,100
Venezuela	650	30	1,300	40	6,100	8,120	700	30	1,350	40	6,100	8,220
Brazil	2,700	850	4,200	250	100	8,100	2,750	850	4,250	250	100	8,200
Union of South Africa	4,000	460	1,600	280	400	6,740	4,100	470	1,700	280	400	6,950
Belgium	4,100	350	1,300	400	500	6,650	4,150	350	1,300	400	500	6,700
Denmark	2,700	700	2,100	350	200	6,050	2,700	800	2,500	350	200	6,550
China	1,300	2,800	1,800	300	400	6,600	1,300	2,800	1,700	300	400	6,500
Egypt	750	1,700	2,700	150	430	5,730	800	1,800	2,800	200	450	6,050
French West Africa	335	100	4,880	40	10	5,365	340	100	4,900	40	10	5,390
Cuba	620	70	3,900	40	120	4,750	750	80	4,200	50	120	5,200
Chile	650	100	4,000	70	50	4,870	700	100	4,100	70	50	5,020
Norway	1,500	500	2,450	150	200	4,800	1,500	500	2,500	150	200	4,850
Trinidad	120	70	4,000	30	300	4,520	120	70	4,150	30	350	4,720
British Malay	1,000	300	2,800	120	200	4,420	1,000	300	2,900	120	200	4,520
New Zealand	2,500	200	1,200	100	200	4,200	2,550	200	1,300	100	200	4,350
Philippine Islands	1,000	600	2,400	90	130	4,220	1,000	600	2,500	90	130	4,320
Hawaiian Islands	1,050	150	2,130	70	70	3,470	1,200	200	2,400	100	100	4,000
Spain	2,900	200	1,700	100	200	5,100	2,300	180	1,300	100	120	4,000
Iraq	350	230	2,300	60	800	3,740	350	230	2,400	60	800	3,840
Switzerland	1,650	170	1,200	150	100	3,270	1,750	170	1,300	150	100	3,470
Poland	600	1,000	450	300	450	2,800	800	1,100	600	350	500	3,350
Panama Canal Zone	120	30	2,460	20	40	2,670	130	30	2,770	30	40	3,000
Ceylon	347	223	2,289	25	5	2,889	355	235	2,370	30	10	3,000
Colombia	710	100	1,500	30	110	2,450	800	130	1,900	20	125	2,975
Peru	550	210	1,800	30	320	2,910	500	200	1,700	30	300	2,730
Greece	550	150	1,500	60	120	2,380	550	150	1,600	60	130	2,490
Uruguay	450	250	1,650	40	40	2,430	450	250	1,700	40	40	2,480
Irish Free State	1,150	520	270	70	250	2,260	1,200	550	280	70	250	2,350
Czechoslovakia	1,820	630	560	270	50	3,330	1,200	400	390	200	30	2,220
Finland	1,000	550	100	120	120	1,890	1,050	550	130	120	120	1,970
Hungary	590	480	640	110	110	1,930	600	480	650	110	120	1,960
Algeria	950	300	400	80	120	1,850	950	300	405	80	120	1,900
Puerto Rico	520	70	1,060	30	40	1,720	540	80	1,100	35	45	1,800
Palestine	350	390	600	25	170	1,535	380	440	650	30	200	1,700
Jamaica	200	50	1,300	10	30	1,590	210	55	1,310	10	35	1,620
Portugal	610	400	350	70	70	1,500	620	410	360	70	70	1,530
French Morocco	820	90	150	40	140	1,240	830	90	150	40	140	1,250
Hongkong	225	50	700	90	10	1,075	240	60	790	100	10	1,200
Turkey	335	315	430	55	15	1,150	340	320	440	60	17	1,177
Kenya and Uganda	370	150	540	25	10	1,095	375	145	545	25	10	1,100
Siam	170	340	320	50	50	930	190	360	340	60	60	1,010
Austria	900	300	1,200	160	160	2,720						
Miscellaneous[b]	5,083	2,891	4,437	623	871	13,905	5,337	3,040	4,626	657	915	14,575
	751,477	145,321	757,621	57,156	203,281	1,914,856	764,857	148,455	732,451	56,227	205,517	1,907,507

[a] Consumption figures include crude consumed as such, all its products and related fuels such as benzol, natural gasoline alcohol used as motor fuel. Oil delivered to ships' bunkers is included in consumption of country where deliveries are made.

[b] See Table 5.

TABLE 5.—*World Consumption of Petroleum and Related Fuels in Miscellaneous Countries*[a]

BARRELS

Country	1937						1938					
	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total	Motor Fuel	Kerosene	Gas and Fuel Oil	Lubricants	?Miscellaneous	Total
Yugoslavia	280,000	180,000	285,000	70,000	115,000	930,000	290,000	190,000	295,000	72,000	118,000	965,000
Tunis	356,000	183,000	320,000	28,000	5,000	892,000	370,000	190,000	350,000	30,000	7,000	947,000
Indo China	270,000	310,000	110,000	27,000	110,000	827,000	275,000	315,000	114,000	30,000	115,000	849,000
Sarawak	11,000	32,500	745,000	3,500	15,000	807,000	12,000	33,000	750,000	4,000	15,000	814,000
Bulgaria	140,000	290,000	180,000	75,000	65,000	750,000	150,000	300,000	185,000	80,000	70,000	785,000
Syria	275,000	240,000	130,000	25,000	38,000	708,000	280,000	250,000	135,000	27,000	40,000	732,000
Gold Coast	200,000	75,000	170,000	40,000	35,000	520,000	220,000	80,000	170,000	45,000	35,000	550,000
Guatemala	103,500	30,200	376,000	700	12,600	523,000	108,000	31,000	365,000	1,000	13,000	518,000
Latvia	150,000	189,000	6,000	24,000	31,000	400,000	155,000	200,000	7,000	25,000	33,000	420,000
Bolivia	100,000	20,000	200,000	20,000	20,000	360,000	110,000	22,000	220,000	24,000	24,000	400,000
Italian E. Africa	180,000	90,000	50,000	30,000	30,000	380,000	190,000	95,000	53,000	32,000	30,000	400,000
Ecuador	147,000	40,000	48,000	2,000	133,000	370,000	155,000	43,000	53,000	2,000	137,000	390,000
Malta	77,000	125,000	135,000	10,000	4,000	351,000	80,000	126,000	145,000	10,000	5,000	366,000
Southern Rhodesia	202,300	18,500	101,000	21,700	500	344,000	210,000	20,000	105,000	23,000	1,000	359,000
Estonia	125,000	60,000	75,000	30,000	40,000	330,000	135,000	65,000	80,000	30,000	40,000	350,000
Belgian Congo	250,000	18,100	44,400	15,500	10,000	338,000	252,000	19,000	45,000	16,000	10,000	342,000
Lithuania	210,000	40,000	67,000	28,000	1,000	346,000	200,000	40,000	65,000	24,000	1,000	330,000
Dominican Republic	93,200	34,800	182,000	11,300	6,700	328,000	93,800	35,000	182,900	11,800	6,500	330,000
Nigeria	180,000	84,000	26,000	16,600	400	307,000	190,000	90,000	28,000	17,200	800	326,000
Nicaragua	90,000	28,000	80,000	10,000	10,000	218,000	95,000	29,000	85,000	10,000	10,000	229,000
Cyprus	51,500	30,400	112,300	4,500	300	199,000	52,600	30,400	117,000	4,700	300	205,000
Iceland	107,000	26,000	51,000	5,750	250	190,000	113,000	28,000	56,000	5,700	300	203,000
Tanganyika	85,600	43,000	61,400	1,800	200	192,000	87,000	44,000	62,000	1,800	200	195,000
Newfoundland	110,000	20,000	10,000	10,000	2,000	152,000	115,000	22,000	10,500	10,500	2,000	160,000
Bermuda	13,900	17,700	117,500	500	400	150,000	14,500	17,600	125,000	500	400	158,000
Haiti	63,200	27,300	40,100	7,500	1,900	140,000	66,000	28,000	43,000	9,000	2,000	148,000
Madagascar	70,000	30,000	22,000	1,000	1,000	124,000	75,000	35,000	25,000	1,000	1,000	137,000
Barbados	60,300	23,900	35,000	3,800	1,000	124,000	65,000	26,000	37,000	4,000	1,000	133,000
British Guiana	29,000	13,100	76,500	5,200	200	124,000	30,200	13,100	83,000	5,500	200	132,000
Mozambique	61,500	23,200	26,000	11,500	800	123,000	65,000	24,000	27,000	12,000	1,000	129,000
Fiji Islands	41,000	8,500	45,000	3,400	100	98,000	42,800	8,800	47,700	3,500	200	103,000
Others	950,000	540,000	510,000	80,000	180,000	2,260,000	1,040,000	590,000	560,000	85,000	195,000	2,470,000
	5,083,000	2,891,200	4,437,200	623,250	870,350	13,905,000	5,336,900	3,039,900	4,626,100	657,200	914,900	14,575,000

[a] Consumption figures include crude consumed as such, all its products and related fuels such as benzol, natural gasoline, alcohol used as motor fuel. Oil delivered to ships' bunkers is included in consumption of country where deliveries are made.

tion of natural and synthetic petroleum; also, that the Rumanian fields, now more accessible to Germany, produce about 35,000,000 in excess of Rumanian consumption.

The outstanding developments during the year were: the decline of 35,000,000 bbl. of consumption in the United States and the increase in

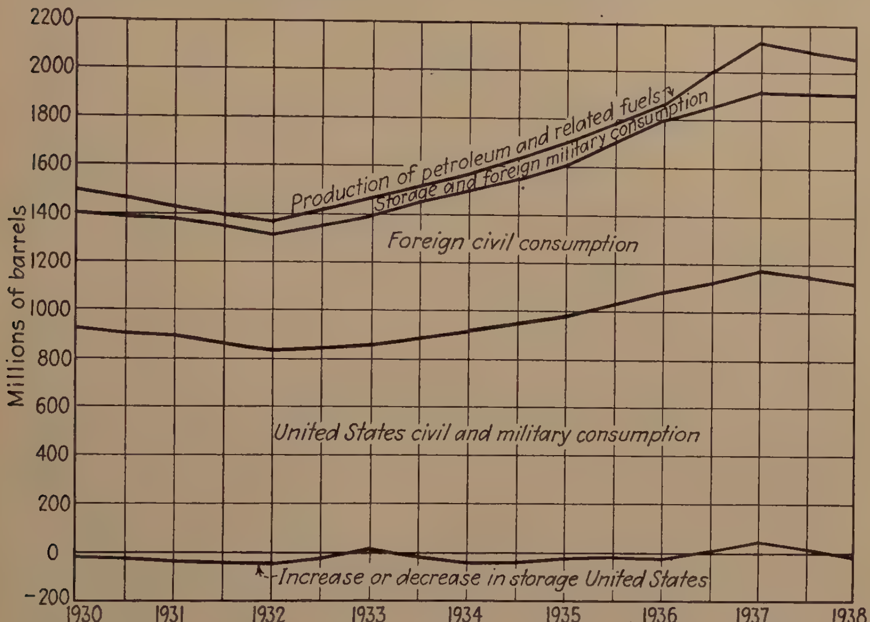

FIG. 1.—WORLD PRODUCTION AND CONSUMPTION OF PETROLEUM AND RELATED FUELS.

military consumption, chiefly in Japan, China and Spain. The decline in the production of Mexico and the continued high production of synthetic oils in Germany are also worth mentioning.

The writers present, for the first time, a detailed tabulation (Table 5) of the countries that individually consume less than 1,000,000 and more than 100,000 bbl. a year and that are grouped under the heading of "miscellaneous" in the main table of Consumption.

Chapter IV. Production

Introduction

By James Terry Duce,* Member A.I.M.E.

In order to facilitate interpretation of the data in this chapter, we print the following excerpts from circulars to authors, compiled by Mr. Frank A. Herald when he was Vice-chairman for Production of the Petroleum Division, and revised in 1939.

Generally in Table 1 the unit for presentation of data is a field. For our purposes a field is defined as the whole of a surface area wherein productive locations are continuous. Such unit commonly includes and surrounds nonproductive areas. Such unit commonly includes a great variety of geologic conditions—several units of continuous productive reservoirs of distinctly different structure and of distinctly different stratigraphy. Therefore it is hoped that our authors will subdivide "field" so as to enable students to make analyses that may have scientific and/or commercial value.

As to each space in the tabulation, it is either (1) not applicable, (2) the proper entry is not determinable, (3) the proper entry is determinable, but not determinable from data available to the author, (4) the proper entry is determinable by the author. In spaces not applicable, the author will please draw horizontal lines; in spaces where the proper entries are not determinable, the author will please insert x; in spaces where the proper entries are determinable but not determinable from data available to the author, the author will please insert y; in spaces where the proper entries are determinable by the author he will, of course, make such entries. Generally, y implies a hope that in some future year a definite figure will be available.

Inability to determine precisely the correct entry for a particular space should not lead the author to insert merely y. Contributions of great value may be made by the author in many cases where entries are not subject to precise determination. In such cases the author should use his good judgment and make the best entry possible under the circumstances. For many spaces, the correct entries represent the opinion of the author (for example, "Area Proved") and in such cases the entries need not be hedged to such extent as in cases where the quantities are definite yet can be ascertained only approximately by the author.

In cases under definite headings but where figures are only approximate, the author may use x. For example, if the total production of a field is known to be between 1,800,000 and 1,850,000, the author may report 1,8*xx*,*xxx*; or if the production is between 1,850,000 and 1,900,000, the author may report 1,9*xx*,*xxx*.

Where a numeral is immediately to the left of x or y, such numeral represents the nearest known number in that position.

As to quantity of gas produced from many fields the question will arise as to whether the figures should include merely the gas marketed or should include also estimates of gas used in operations and gas wasted. Although rough approximations

* Geologist, The Texas Company, New York, N. Y.; Chairman for Production, A.I.M.E. Petroleum Division, 1936–1937, 1937–1938 and 1938–1939.

may be involved, our figures should represent as nearly as possible the total quantity of gas removed from the reservoir.

While we have not provided a column for showing the thickness of the productive zone, generally the difference between average depth to bottoms of productive wells and average depth to top of productive zone will represent approximately the average thickness of the productive zone. For fields where this is not true because of unusually high dips, or for other reasons, it is suggested that the authors indicate in their texts the approximate average thickness of the productive zone.

The figure representing net thickness of producing rock should correspond to the total of the net portions of the producing zone which actually yield oil into the drill hole. It is recognized that for some fields the authors can make only rough guesses—so rough that figures would be of no value. In such cases the authors should enter either x or y, whichever is more appropriate.

We are particularly anxious to have every author give due consideration to the determination of structural conditions of each oil and/or gas body. Please consider each oil and/or gas reservoir and indicate its structure. The mere fact that a reservoir is on an anticline is not proof that the structural condition affecting the accumulation is anticlinal; for example, an oil and/or gas body limited by the upper margin of a lens on the limb of an anticline is "ML" as to structure. By all means, if the oil body occupies any position in the lens other than its upper limit, please so indicate clearly by footnote, for "ML" means, unless modified, that the accumulation is at the upper part of the lens. In every case where the oil and/or gas body terminates short of the up-dip continuity of the reservoir, please carefully check your evidence and then appropriately record your conclusion. "Terrace," "Nose" and "Syncline" are the only terms in our legend which presume such continuity.

In Table 2 are listed the important wildcat wells completed during the year. By the term "important" is meant: wells discovering new fields; wells resulting in the discovery of important extensions to old fields; wells discovering new zones in old fields; wells condemning important areas or resulting in significant stratigraphic information, even if the wells are dry; and exceptionally deep wells. At the foot of this table the total number of wells drilled in each district is given, segregated as to oil wells, gas wells and dry holes. The number of wells drilling on Dec. 31, 1938 are in two divisions, designated as wildcat wells and wells in proven fields.

Footnotes to Column Headings—Table 1

[a] Areas where both oil and gas are produced are included under heading "Oil."

[b] Wells producing both oil and gas are classified as "Producing Oil."

[c] Gas wells are those producing gas, but include those producing wet gas, from which casinghead gasoline may be produced.

[d] Bottom-hole pressures are preceded by "e." All other figures represent pressures at casinghead with well closed.

[e] Cam, Cambrian; Ord, Ordovician; Sil, Silurian; Dev, Devonian; Mis, Mississippian; MisL, Lower Mississippian; MisU, Upper Mississippian; Pen, Pennsylvanian; Per, Permian; Tri, Triassic; Jur, Jurassic; CreL, Lower Cretaceous; CreU, Upper Cretaceous; Eoc, Eocene; Olig, Oligocene; Mio, Miocene; Pli, Pliocene.

[f] S, sandstone; SH, sandstone, shaly; Ss, soft sand; H, shale; L, limestone; LS, limestone, sandy; C, chalk; A, anhydrite; D, dolomite; Da, arkosic dolomite; GW, granite wash; P, serpentine; O, oölite; Slt, siltstone.

[g] Figures are entered only for fields where the reservoir rock is of pore type. Figures represent ratio of pore space to total volume of net reservoir rock expressed in per cent. "Por" indicates that the reservoir rock is of pore type but said ratio is not known by the author. "Cav" indicates that the reservoir rock is of cavernous type; "Fis," fissure type.

[h] A, anticline; AF, anticline with faulting as important feature; Af, anticline with faulting as minor feature; AM, accumulation due to both anticlinal and monoclinal structure; H, strata are horizontal or near horizontal; MF, monocline-fault; MU, monocline-unconformity; ML, monocline-lens; MC, monocline with accumulation due to change in character of stratum; MI, monocline with accumulation against igneous barrier; MUP, monocline with accumulation due to sealing at outcrop by asphalt; D, dome; Ds, salt dome; T, terrace; TF, terrace with faulting as important feature; N, nose; S, syncline.

[i] Information will be found in text as indicated by symbols; A, name of author, other than above, who has compiled the data on the particular field; C, chemical treatment of wells; G, gas-oil ratios; P, proration; U, unit operation; R, references; W, water; O, other information.

Oil and Gas Development in South Arkansas in 1938

By Warren B. Weeks,* Associate Member A.I.M.E.

(New York Meeting, February, 1939)

The development of the relatively deeper fields discovered during 1937 helped build the 1938 production to 18,456,760 bbl., an increase of 6,295,910 bbl., or 51.6 per cent over 1937, and the largest production for south Arkansas since 1930.

Schuler and Rodessa accounted for the increased production as well as for over half of the wells drilled in the state. There were 243 holes drilled during 1938, of which 200 were completed as oil or gas wells. Of the 29 wildcat wells completed, 25 were dry, 3 found oil in the Smackover limestone, while 1 made a small oil well in the Nacatoch sand. This was less than half the number of wildcats drilled the previous year, but nearly twice as many field wells were drilled. The old depth record of 7973 ft. was exceeded twice during the year, with the present record of 8332 feet.

Trend of Prospecting

The porous "Reynolds" oölite of the Smackover limestone[1] has been the object of most of the wildcat prospecting during the past two years. Seismograph work, which brought 22 crews into this area during 1938, was largely pointed toward a study of the structure of this limestone formation. Thirteen dry wildcats have been drilled to this formation and five pools have been opened in it since it was first found to be productive at Snow Hill in the spring of 1936.

With the failure of "updip" prospects to produce, activity moved southward and basinward. Success in five instances in Columbia and south Union Counties has spurred activity in this area. Much of the acreage is under lease and half a dozen deep limestone tests are assured for the current year.

Fig. 1 shows the location of the principal oil fields in south Arkansas, as well as one or two minor producing areas. The fields are numbered in the order of their discovery. It is shown that most of the recent discoveries are from the deeper formations. Dry wildcats that penetrated

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[1] W. B. Weeks: South Arkansas Stratigraphy with Emphasis on the Older Coastal Plain Beds. *Bull.* Amer. Assn. Petr. Geol. (Aug. 1938) **22**, 953–983.

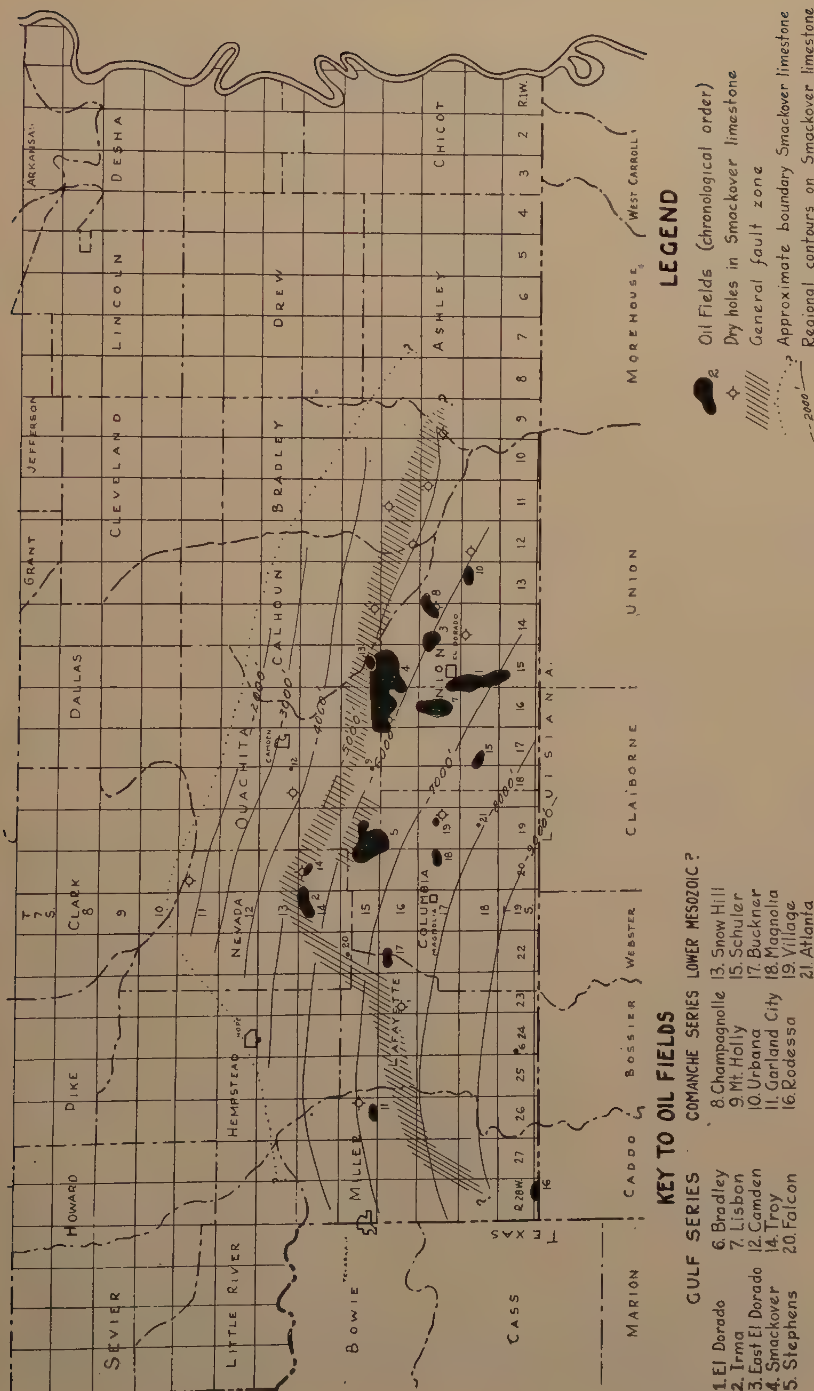

FIG. 1.—INDEX MAP OF SOUTH ARKANSAS.

the Smackover limestone are indicated. Contours drawn on the limestone at 1000-ft. intervals show the regional dip.

Two important wildcats drilling along the faulted area have found oil saturation in the limestone. The low permeability of the limestone at these two locations may result in failure to produce commercially. The two tests that are in process are those of the Shell Petroleum Co. and Ohio Oil Co., Warren No. 1, sec. 13, T. 16 S., R. 24 W., and Deep Rock Oil Co. et al., Wesson No. 1, sec. 23, T. 14 S., R. 19 W. The Shell well cut a fault showing a displacement of over 1000 ft. within the Comanche series.

New Fields

Magnolia.—On March 29, 1938, the Kerlynn Oil Company's Barnett No. 1, sec. 14, T. 17 S., R. 20 W., central Columbia County, was completed for 350 bbl. per day of 38° gravity oil from the "Reynolds" öolite at 7646 ft. This was the first of three discovery wells for the year in this zone near the top of the Smackover limestone. The discovery well was completed with difficulty and produced a small percentage of salt water. Three wells drilled to the east and west and slightly north were dry, but by the end of the year five oil wells had been completed south of the discovery well and the field had produced a total of 130,470 bbl. of oil. The field was named for the town of Magnolia, 5 miles to the west.

Wide-spacing of one well to 40 acres is the present program for this field. It is being developed in a slow, orderly manner. By Feb. 1, 1939, there were eight oil wells and five drilling wells. It is expected that most of the acreage will be drilled during 1939 with an ultimate 40 to 50 oil wells. Present field allowable is 3000 bbl. per day. With only 260 proven acres for production at the end of the year, it is believed that the field will cover more area. This "structure" was located with a seismograph.

Village.—On May 26, 1938, the Standard Oil Company of Louisiana brought in its Phillips No. 1, sec. 15, T. 17 S., R. 19 W., Columbia County, for 270 bbl. of 40° gravity oil per day on $\frac{3}{16}$-in. tubing choke from the "Reynolds" oölite at 7420 ft. There were three more wells completed by the end of the year and 60,385 bbl. of oil had been produced. The highest well topped the porosity only 55 ft. above the water level, 7125 ft. subsea. The vertical column of oil is between 20 and 25 ft. and the porosity is much more erratic than at Magnolia. Consequently three of the wells have high gas-oil ratios, owing to the difficulty of completing the wells. Only 160 acres are proven for production at present and the field is expected to extend over only a small area with relatively poor recovery per acre. This field received its name from the near-by community of Village. The anticlinal structure was originally determined with seismograph instruments.

Falcon.—The third new field for 1938 was 2 miles southeast of the small community of Falcon, in Nevada County, where the Texas-Canadian Oil Corporation completed its No. 1 Stocks, in sec. 9, T. 15 S., R. 22 W. on Sept. 18, pumping approximately 15 bbl. of oil and over 60 per cent salt water per day. This production of 14° gravity oil was

TABLE 1.—*Oil and Gas Production in South Arkansas in* 1938

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres: Oil	Area Proved, Acres: Gas[5,a]	Total Oil Production, Bbl.: To End of 1938	Total Oil Production, Bbl.: During 1938	Total Gas Production, Millions Cu. Ft.: To End of 1938	Total Gas Production, Millions Cu. Ft.: During 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Producing Oil[b]	At End of 1938: Producing Gas[c]	Oil Production Methods at End of 1938, Number of Wells: Flowing	Oil Production Methods at End of 1938, Number of Wells: Artificial Lift
1	Atlanta, *Columbia*	0.1	40[4]	0	1,970	1,970	0	0	1	1	0	1	0	1	0
2	Bradley, *Lafayette*	14	80	0	186,705	0	0	0	6	0	0	0	0	0	0
3	Buckner, *Columbia and Lafayette*	1	440[4]	0	362,390	340,900	0	0	9	8	0	9	0	7	2
4	Camden, *Ouachita*	4	10	0	36,830	910	0	0	1	0	0	1	0	0	1
5	Champagnolle, *Union*	12	2,000*x*	*x*	13,613,385	454,065	*x*	*x*	233	8	1	76	1	6	70
6	East El Dorado, *Union*[1]	17	1,420*x*	*x*	9,122,545	146,280	*x*	0	187	0	4	59	3	0	59
7	El Dorado, *Union*	19	8,000*x*	*x*	47,001,210	524,230	*x*	0	1,115	0	8	206	0	0	206
8	Falcon, *Nevada*	0.3	20[4]	0	136	136	0	0	2	2	0	2	0	0	2
9	Garland City, *Miller*[2]	7	300	0	1,742,010	135,995	0	0	28	0	0	19	0	0	19
10	Irma, *Nevada*	18	900*x*	*x*	6,441,660	235,235	*x*	0	150	2	6	64	0	0	64
11	Lisbon, *Union*	13	2,700*x*	*x*	6,537,545	98,080	*x*	0	356	0	0	144	0	0	144
12	Magnolia, *Columbia*	0.8	260[4]	0	130,470	130,470	*x*	*x*	6	6	0	6	0	6	0
13	Mt. Holly, *Ouachita*	10	60	0	117,085	0	0	0	6	0	0	0	0	0	0
14	Rodessa, *Miller*[3]	1.5	1,900[4]	200	3,671,185	2,436,140	14,399	12,673	109	49	1	97	5	32	70[6]
15	Schuler, *Union*	1.8	4,250[4]	0	7,477,675	6,267,845	*y*	*y*	131	109	0	131	0	119	12
16	Morgan Sands	1.8	350	0	1,495,895	653,640	*y*	*y*	14	0	0	11	0	0	11
17	Jones Sand	1.3	3,000	0	5,531,320	5,197,775	*y*	*y*	110	101	0	110	0	109	1
18	Reynolds Oolite	1.2	900	0	450,460	416,430	*y*	*y*	10	8	0	10	0	10	0
19	Smackover, *Ouachita and Union*	17	25,760	*x*	372,245,125	6,543,205	*x*	*x*	3,736	4	39	1,746	0	0	1,746
20	Heavy Oil Area	17	16,000*x*	*x*	318,849,935	5,782,285	*x*	*x*	*y*	4	36	1,199	0	0	1,199
21	Light Oil Area	17	9,600*x*	*x*	53,262,810	724,340	*x*	*x*	*y*	0	3	543	0	0	543
22	Snow Hill Area	3	160	0	132,480	36,580	*y*	0	6	0	0	4	0	0	4
23	Stephens, *Columbia, Nevada and Ouachita*	17	3,000*x*	*x*	6,163,195	201,795	*x*	0	306	2	0	190	0	0	190
24	Troy, *Nevada*	3	290	0	722,475	436,915	*y*	*y*	18	2	0	17	0	0	17
25	Urbana, *Union*	9	500*x*	*x*	4,538,935	433,205	*x*	0	48	3	0	34	0	0	34
26	Village, *Columbia*	0.6	160[4]	0	69,385	69,385	*y*	*y*	4	4	0	4	0	4	0
	Total		52,250*x*	200	480,181,916	18,456,761			6,452	200	59	2,806	9	175	2,636

[a] Footnotes to column heads and explanation of symbols are given on page 240.
[1] Including other small producing areas.
[2] Includes the single Glen Rose producer in sec. 24, T. 15 S., R. 26 W.
[3] Information largely furnished by L. D. Bartell, Dallas, Texas.
[4] Areas of the Atlanta, Buckner, Falcon, Magnolia and Village fields are still undefined. Only slight extension of area is expected at Rodessa and Schuler.
[5] Champagnolle, East El Dorado, El Dorado, Irma, Libson and Smackover produced large quantities of gas in earlier years, some of which was used commercially. Stephens produced some gas from the Nacatoch and Urbana from the 2700-ft. sand. The gas at Snow Hill was quickly dissipated. The Jones sand and Reynolds öolite at Schuler have gas reserves, but gas is not being produced commercially at present although 800,000 M cu. ft. was taken from the Reynolds öolite in 1937.
[6] 11 pumping, 59 gas lift.

obtained from perforations in the Nacatoch sand after the well had been plugged back from the top of the Travis Peak formation, where it was dry. Only one more well was completed by the end of the year and the total production amounted to only 136 bbl. of oil. Little more development is expected in this field, which is located on a faulted structure that had been partly determined by former drilling.

Atlanta.—On Dec. 16, 1938, Tidewater Associated Oil Corporation and Seaboard Oil Corporation completed Beene No. 1, sec. 15, T. 18 S., R. 19 W., Columbia County, for 200 bbl. of 44° gravity oil per day through ⅛-in. tubing choke. This production is from the "Reynolds" öolite at 8312 ft. and was the third Smackover limestone field for the

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1938	Producing Formation								Deepest Zone Tested to End of 1938	
	Initial	Average at End of		Gravity A.P.I. at 60° F.	Name	Age[e]	Depth, Average in Feet		Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
		1937	1938	Weighted Average			Bottoms of Productive Wells	To Top of Productive Zone						
1	e3,844	x	e3,844	42.7	Smackover ls.	L Mes?	8,227	8,202	O	17.6	25	A	Smackover ls.	8,332
2	y	x	x	27	Buckrange ss.	CreU	2,790	2,785	S	Por	5	A	Paluxy	3,555
3	e3,200	e3,200	e2,965	32	Smackover ls.	L Mes?	7,260	7,200	O	10 to 20	60	A	Smackover ls.	7,444
4	y	y	y	17	Nacatoch ss.	CreU	1,369	1,356	S	Por	13		Travis Peak	2,500
5	y	y	y	36	Tokio ss., Travis Peak	CreU, CreL	2,800–3,350	2,780–3,340	S	Por	15	NL	Rock salt	6,911
6	y	y	y	20	Nacatoch ss.	CreU	2,180	2,170	S	Por	10	TL	Cotton Valley	6,003
7	y	y	y	32	Nacatoch ss.	CreU	2,177	2,100–2,550–2,950	S	Por	20	ANL	Travis Peak	3,396
8	y	x	y	14	Nacatoch ss.	CreU	1,215	1,203	S	Por	20	AF	Travis Peak	3,654
9	y	y	y	30	Paluxy, Rodessa Member	CreL	2,935–4,215	2,925–4,200	S	Por	10	ML	Smockover ls.	7,310
10	y	y	y	14	Nacatoch ss.	CreU	1,179	1,150	S	Por	15	AF	Travis Peak	3,735
11	y	y	y	35	Nacatoch ss.	CreU	2,120	2,100	S	Por	20	ML	Travis Peak	3,509
12	e3,555	x	e3,200	38.4	Smackover ls.	L Mes?	7,600	7,350	O	16.1	100	A	Smackover ls.	7,789
13	y	x	x	30	Travis Peak	CreL	2,813	2,800	S	Por	7	ML?	Travis Peak	3,378
14	2,350	1,650	e650	42.2	Rodessa Member	CreL	6,100	6,050	LS & O	5 to 30	25	AF	Lower Glen Rose	6,514
15				32		L Mes?					88	A	Smackover ls.	8,328
16	y	y	y	41	Cotton Valley	L Mes?	5,885	5,600	S	15.0	20	A		
17	e3,520	e3,450	e2,750	32	Cotton Valley	L Mes?	7,610	7,530	S	17.6	42	A		
18	e3,545	e3,545 ±	e3,405	36.8	Smackover ls.	L Mes?	7,635	7,600	O	14.3	26	A		
19	y	y	y	21							100	AF		7,973
20	y	y	y	21	Nacatoch ss., Graves ss., Tokio ss.	CreU	2,025–2,475–2,610	2,000–2,450–2,600	S	Por	40	Af	Rock salt	7,255
21	y	y	y	25	Nacatoch ss., Meekin ss.	CreU	2,025–2,300	2,000–2,275	S	Por	30	ALf	Igneous rock	7,973
22	y	y	y	35	Smackover ls.	L Mes?	4,960	4,800	O	25	30	AF	Rock salt	5,708
23	y	y	y	28	Nacatoch ss., Buckrange ss.	CreU	1,510–2,110	1,500–2,100	S	Por	15 7	NLF	Cotton Valley	4,502
24	y	y	y	14 21	Nacatoch ss., Tokio ss.	CreU	1,250–2,167	1,243–2,160	S	Por	10	F	Rock salt	6,143
25	y	y	y	20	Nacatoch ss., Travis Peak	CreU, CreL	2,280–3,560	2,270–3,550	S	Por	10	A	Cotton Valley	4,501
26	e3,350	x	e3,320	40.8	Smackover ls.	L Mes?	7,450	7,390	O	14	50	A	Smackover ls.	7,603

year. The anticlinal structure was worked out by seismograph. The field received its name from a small town 3 miles to the south. A maximum of 25 ft. of oil-saturated oölite was penetrated. The well has been shut in for lack of pipe-line outlet since completion. No estimate can be made as to the areal extent of the pool. It is expected that operators

TABLE 2.—*Summary of Drilling Operations in South Arkansas in* 1938

Important Wildcats Drilled in 1938

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Sec.	Twp.	Rge.			
1	Bradley	9	16 S	11 W	5,143	Quaternary	Smackover ls.
2	Columbia	15	18 S	19 W	8,332	Claiborne	Smackover ls.
3	Columbia	14	17 S	20 W	7,740	Claiborne	Smackover ls.
4	Columbia	15	17 S	19 W	7,603	Claiborne	Smackover ls.
5	Desha	34	8 S	3 W	4,915	Quaternary	Igneous rock
6	Hempstead	1	11 S	25 W	2,290	Saratoga	Eagle Mills
7	Hempstead	5	12 S	26 W	3,511	Nacatoch	Eagle Mills
8	Nevada	9	15 S	22 W	3,654	Claiborne	Travis Peak
9	Pulaski	2	1 S	13 W	4,080	Wilcox	Paleozoic
10	Union	5	18 S	14 W	6,905	Claiborne	Smackover ls.
11	Union	8	18 S	12 W	6,511	Claiborne	Smackover ls.
12	Union	12	17 S	14 W	3,184	Claiborne	Travis Peak
13	Union	18	18 S	17 W	8,328	Claiborne	Smackover ls.

Important Wildcats Drilled in 1938

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Phillips Petr. Co.						Dry hole
2	Tide Water Assoc. Oil Corp. and Seaboard Oil Corp.	200		1/8	1,900	1,610	Discovery, Atlanta pool. Deepest well in Arkansas
3	Kerlyn Oil Co.	500		3/8	1,025	1,325	Discovery, Magnolia pool
4	Standard Oil Co.	270		3/16	2,700	1,900	Discovery, Village pool
5	Columbian Fuel Corp.						Dry hole
6	Davidson & Todd						Dry hole
7	H. D. Easton et al.						Dry hole
8	Texas-Canadian Oil Corp.	15		pump			Nacatoch sand discovery, Falcon pool
9	A. L. Kitselman						Dry hole
10	Fohs Oil Co.						Dry hole
11	Modisett Drilling Co.						Dry hole
12	J. R. Lockhart		1.5	open			Slight extension Rainbow pool
13	Phillips Petr. Co.	282		12/64	600	1,390	Deepest well at Schuler, second deepest in Arkansas

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1938	38	16
Number of oil wells completed during 1938	195	4
Number of gas wells completed during 1938	1	0
Number of dry holes completed during 1938	18	25

will be slow to develop such deep production in the face of the current lack of demand for the oil.

Extensions and Developments

Champagnolle (Rainbow).—In the later part of July 1938, J. R. Lockhart completed Raulston No. 1, sec. 12, T. 17 S., R. 14 W., along the southeast edge of the old Rainbow City pool, for a small gas well. Production was from a fine, silty sand at the top of the zone of lenticular sands of the Travis Peak formation that are productive in that field. Five dry holes and seven oil wells were drilled in this vicinity during the remainder of the year. These wells have small initial production and quickly settle to a pumping stage. The extension proved negligible and little further development is expected.

Schuler.—The Schuler field led in drilling development for this area during 1938 with 101 oil wells completed in the "Jones" sand and 8 in the "Reynolds" oölite. With 3000 acres proven for the "Jones" sand, this reservoir is expected to extend over 3500 acres ultimately. The drilling development was practically completed by the end of 1938 with 10 or 20 wells yet to be drilled. The reservoir pressure has dropped rapidly, especially in the eastern part of the field, where the sand is less permeable. It is probable that there is no very effective water drive and that the gas cap is enlarging as the oil is withdrawn. Various efforts of the operators to agree on plans for pressure maintenance have failed and there is now little chance for any such program.

Other Fields.—Although 49 wells were drilled in Rodessa, Miller County, during 1938, the productive area was not extended appreciatively. Reservoir pressure has dropped to 650 lb. and most of the wells are on some sort of mechanical lift. Very little more development is expected. The Buckner field, Columbia County, was being developed slowly on a 40-acre spacing pattern with only eight wells completed during 1938. Because of curtailed production, the reservoir pressure has dropped very little.

There was little drilling development in other old fields. Two small pumpers were completed from the Buckrange sand on the northwest edge of the Stephens field, Columbia and Nevada Counties. In Nevada County the Irma field had two Nacatoch sand pumpers while the near-by Troy field had two pumpers from the Tokio sand. Three small pumpers were completed from the Nacatoch sand on the south side of the Urbana field, Union County. Three Meekin sand pumpers were completed on the Norphlet side of the Smackover field, Union County. There is a general belief that much of the water trouble in this field may be due to casing leaks and original faulty completion. It is expected that the higher part of the reservoir may be generally redrilled in order to recover

much oil that was trapped by water-coning under former flush production methods.

Well Spacing

There has been a noticeable trend toward wider well spacing in the recent deeper drilling of this area. The initial step was the development of the "Jones" sand in the Schuler field with one well for 20 acres. With the high drilling costs and current low prices of oil, this 20-acre spacing has turned out to be uneconomically close. Development around subsequent deep discoveries has been started on the basis of one well to 40 acres. Deeper drilling may make programs of even wider spacing necessary.

Conservation

Flush production from the deeper fields has been prorated since the beginning of 1938. The Arkansas Board of Conservation has set up an organization to collect various reservoir and production data from these fields. Production is allocated to wells on the basis of acreage represented, bottom-hole pressures and gas-oil ratios. At present the State Legislature is deliberating over measures that have been proposed to give the Conservation body powers that will enable them to control better the conservation of the reservoir energy in the fields and further protect the various rights of the State, property owners, and operators.

Acknowledgments

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Developments in the California Oil Industry during 1938

By V. H. Wilhelm,* Member A.I.M.E.

(New York Meeting, February, 1939)

In contrast with the previous year's activity, the California oil industry for 1938 showed a decrease in drilling, market demand, and discovery of new oil reserves, although there was an increase in oil production. Although additions to reserves from new fields and extensions were less than withdrawals during the year, reappraisals of discoveries in 1937 added to new discoveries during 1938 amounted to over 300,000,000 bbl. The following comparative statement shows the important changes in various phases of the industry:

	1937	1938	Increase or Decrease*
Wells completed	1,156	987	168*
Market demand, bbl	239,000,000	218,000,000	21,000,000*
New oil reserves, bbl	400,000,000	180,000,000	220,000,000*
Oil production, bbl	238,000,000	249,000,000	11,000,000

Throughout the year the storage situation became progressively more acute, owing principally to less Pacific foreign demand, and increased potential from drilling the newly discovered fields and pools (Fig. 1). California storage increased approximately 32,000,000 bbl. during 1938, most of which (approximately 18,000,000 bbl.) was heavy crude and residuum. The market demand for the year was around 600,000 bbl. per day.

Because of the trend toward Diesel power for heavy transportation, the non-gasoline-bearing crudes are fast becoming a drug on the market.

New discoveries were instrumental in increasing the potential production of the state from 1,076,000 bbl. per day in January to an all-time high of 1,420,000 bbl. per day at the close of the year; although the indicated reserves of these new discoveries were not equal to the yearly withdrawal of 249,000,000 bbl. As of the end of 1938, the state was voluntarily curtailed about 58 per cent.

As a result of prospecting during the year, six new fields were discovered, three fields were extended, and deeper zones were reached in five of the older fields.

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San Joaquin Valley

The San Joaquin Valley contributed four new fields, two of which, Coles Levee and Wasco, were the result of applied geophysics.

East Coalinga.—The Avenal (Eocene) was discovered on the southeast-plunging nose of the East Coalinga anticline by the Petroleum Securities Oil Co. in its Gatchell No. 2 well, which was completed flowing at the rate of 5184 bbl. per day of 32° gravity oil from a depth of 6892 ft. Production is coming from 90 ft. of very permeable sand. Later develop-

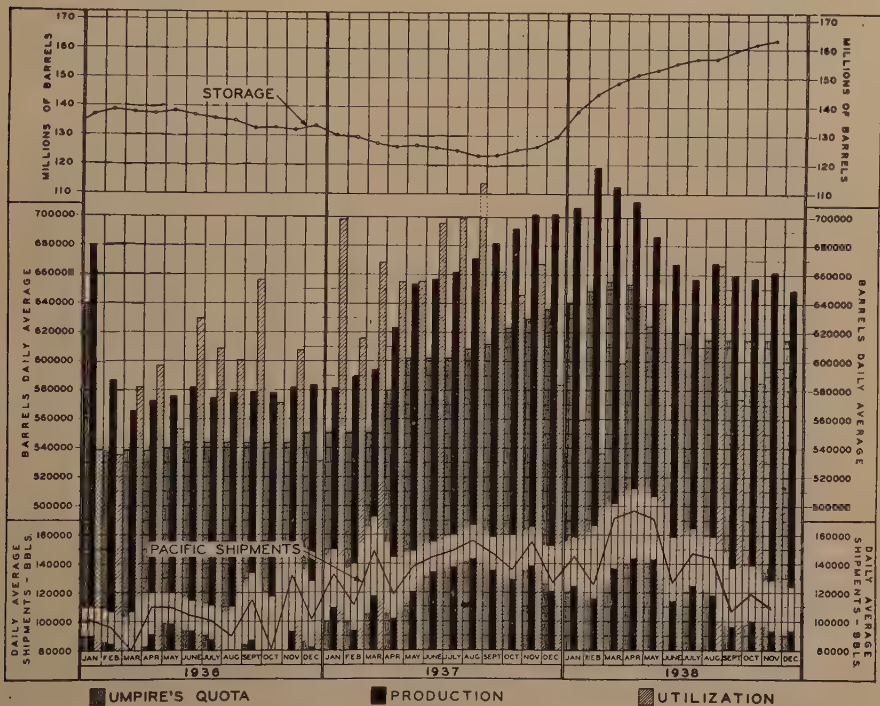

Fig. 1.

ments in the area indicated a maximum thickness of 500 ft. of sand. Shore-line deposits flanking the East Coalinga anticline are the reservoir beds for this accumulation and do not extend under the old proven area. Although the gas-oil ratio averages but 650 cu. ft. per barrel of oil, the wells in this new field are capable of flowing at very high rates under hydrostatic pressure. While it is difficult to predict the ultimate productive area of a shore-line field, present development indicates that this is by far the most important discovery of the year.

Coles Levee.—This field, about 3½ miles southeast of Elk Hills in sec. 10-31-25, was discovered by the Ohio Oil Co. when it completed

TABLE 1.—*Oil and Gas Production in California*

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres	Total Oil Production, Bbl.	
			Oil	To End of 1938	During 1938
	Los Angeles Basin:				
1	Alamitos, *Los Angeles*	11¾	110	22,714,562	601,278
2	Athens, Rosecrans, *Los Angeles*	14¾	295	36,090,185	3,731,105
3	Brea Olinda, *Orange*	58	1,259	161,774,425	2,100,038
4	Coyote, East, *Orange*	28	784	78,782,352	1,242,362
5	Coyote, West, *Orange*	33	880	77,764,944	3,084,436
6	Dominguez, *Los Angeles*	15	810	106,987,665	9,740,197
7	El Segundo, *Los Angeles*	3	700	7,689,505	3,877,508
8	Huntington Beach, *Orange*	18	2,277	270,873,855	11,894,880
9	Inglewood, *Los Angeles*	14	860	111,840,682	5,335,612
10	Lawndale, *Los Angeles*	10½	15	537,191	26,026
11	Long Beach, *Los Angeles*	17½	1,310	616,552,801	20,485,700
12	Los Angeles Dist., *Los Angeles*	36	400	65,481,883	179,976
13	Montebello, *Los Angeles*	22	1,240	107,764,046	4,174,076
14	Playa del Rey, *Los Angeles*	9	640	42,988,948	2,267,955
15	Potrero, *Los Angeles*	11	110	2,485,928	224,985
16	Richfield, *Orange*	20	1,202	85,949,499	3,134,623
17	Santa Fe Springs, *Los Angeles*	19	1,035	447,582,305	12,614,157
18	Seal Beach, *Los Angeles*	13	372	59,505,178	2,596,214
19	Torrance, *Los Angeles*	17	4,060	90,787,832	5,158,751
20	Whittier, *Los Angeles*	37	540	17,701,541	344,166
21	Wilmington, *Los Angeles*	3	3,945	48,266,544	34,005,738
22	Others			3,159,935	249,652
	Coastal District:				
23	Capitan, *Santa Barbara*	9	310	3,379,676	1,066,533
24	Elwood, *Santa Barbara*	10	500	64,424,218	2,247,969
25	Gato Ridge, *Santa Barbara*	7	600	S	1,489,571
26	Las Flores, *Santa Barbara*	½		18,091	18,091
27	Padre Canyon, *Ventura*	3	100	774,630	290,037
28	Rincon, *Ventura*	11	495	9,728,309	1,394,126
29	San Miguelito, *Ventura*	8	300	3,229,904	752,781
30	Santa Barbara, *Sta. Barbara*	10	102	3,095,465	159,004
31	*Santa Maria—Sta. Barbara and San Luis Obispo*			144,315,303	(5,952,320)[2]
32	Cosmalia, *Sta. Barbara*	21	1,010	S[1]	91,803
33	Cat Canyon, *Sta. Barbara*	27	865	S	118,509
34	Santa Maria Valley, *Sta. Barbara*	3	6,000	S	3,287,737
35	Lompoc, *Sta. Barbara*	34	3,060	S	84,900
36	Orcutt, *Sta. Barbara*	36	4,040	S	861,709
37	Summerland, *Sta. Barbara*	46	40	3,135,694	11,453
38	Ventura Ave., *Ventura*	22	1,905	200,331,479	12,916,832
39	*Ventura Newhall-Ventura and Los Angeles*			59,754,100	1,908,218
40	Bardsdale, *Ventura*	44	140		(56,816)
41	Conejo-Oxnard, *Ventura*	44	200		(36,942)
42	Elsmere Canyon, *Los Angeles*	49	60		(0)
43	Ex-Mission, *Ventura*	63	130		(11,904)
44	Hopper Canyon, *Ventura*	50	80		(37,234)
45	Modelo, *Ventura*	40	60		(4,342)
46	Newhall-Potrero, *Los Angeles*	49	315		(241,501)
47	Pico Canyon, *Los Angeles*	63	95		(22,256)
48	Sespe, *Ventura*	37	505		(95,158)
49	Shiells Canyon, *Ventura*	27	350		(375,033)
50	Simi, *Ventura*	26	631		(36,548)
51	Sisar-Silverthread, *Ventura*	53	330		(46,518)
52	South Mountain, *Ventura*	23	725		(526,568)

[1] S indicates that this is reported with Santa Maria.

[2] Figures in parentheses are not added in totaling. They cover small fields of which totals are included in groups, the group total only being used in the grand total.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.: To End of 1938	Total Gas Production, Millions Cu. Ft.: During 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	Number of Oil and/or Gas Wells: During 1938: Completed	Number of Oil and/or Gas Wells: During 1938: Abandoned	Number of Oil and/or Gas Wells: At End of 1938: Producing Oil[b]	Oil-production Methods at End of 1938, Number of Wells: Flowing	Oil-production Methods at End of 1938, Number of Wells: Pumping	Oil-production Methods at End of 1938, Number of Wells: Gas Lift	Pressure, Lb. per Sq. In.[d]: Initial	Pressure, Lb. per Sq. In.[d]: Average at End of 1938	Character of Oil Approx. Average during 1938: Gravity A.P.I. at 60° F., Weighted Average
1						43	1	41	1			26
2	83,128	4,861		31	10	118	31	73	14			35
3	53,786	1,717		1		299		280	19			23
4	} 44.407	3,360		4		85	1	84				21
5				5	4	54	3	51	0			29
6	174,516	19,166		16	3	207	42	125	40			27
7	6,167	3,478		20	8	56	3	50	3			26
8	278,236	14,636		9	20	570	2	563	5			23
9	82,511	3,344		1		208	26	180	2			23
10	1,111					6		6				29
11	825,335	21,993		32	44	1,261	0	1,259	2			25
12	y	y				109		109				15
13	32,621	4,159		32	8	216	24	192				26
14	45,725	2,179		1	13	197	1	196				24
15	2,706			2	2	13	3	10				28
16	77,158	2,605		18	4	285		281	4			21
17	649,792	9,922		2	30	587	1	560	26			32
18	91,152	3,268		1		69	5	55	9			26
19	63,734	3,629		129	6	650	25	625	0			22
20	y	y				148		148				24
21	15,749	14,392		261	4	565	414	150	1			22
22						64		64				
23	1,805	688		6		51	11	40	0			32
24	56,537	3,430				76	3	58	15			36
25				4		9	0	9	0			13
26	with Cat Canyon			1		1		1				14
27	with Rincon			2		8	2	5	1			29
28	10,752	2,058		10		50	12	34	4			27
29	4,783	1,218		2		10	7	3	0			27
30		y		2		35		35				19
31	8,471	1,530										
32				1		2		2				9
33				1		4		4				13
34				75		123	61	62	0			16
35				1		5		5				19
36				2		120		120				17
37				0		8		8				15
38	707,794	36,984		23		251	106	101	44			30
39												
40						28		28				28
41						1		1				12
42						0		0				16
43						23		23				24
44						12		12				14
45						13		13				15
46				4	11	22	3	19				15
47						32		32				38
48						15		15				28
49	with South Mt.			3		108	3	105				30
50						56		56				38
51						67		67				18
52	53,589	3,615		1		85		85				24

[b] Footnotes to column heads and explanation of symbols are given on page 240.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1938	
	Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
1	Repetto-Puente	Pli-Mio	5,797	4,635	SH		1,700	A	Miocene	9,054
2	Repetto-Puente	Pli-Mio	7,718	4,035	SH		3,410	A	Miocene	10,389
3	Repetto-Puente	Pli-Mio	3,867	260	SH		3,000	MF	Miocene	8,201
4	Repetto-Puente	Pli-Mio	4,100	2,450	SH		900	A	Miocene	9,084
5	Repetto	Pli	5,988	2,800	SH		2,100	A	Miocene	8,144
6	Repetto-Puente	Pli-Mio	7,247	3,800	SH		3,000	A	Miocene	10,435
7	Puente	Mio	7,321	6,890	SH		50	A	Schist	8,009
8	Repetto-Puente	Pli-Mio	4,399	1,900	Cong. SH		800	MF	Middle Miocene	9,054
9	Pico-Repetto-Puente	Pli-Mio	6,466	1,073	SH		690	A	Puente	6,508
10	Puente	Mio	6,500	6,375	SH		125	ML	Puente	7,405
11	Pico-Repetto-Puente	Pli-Mio	5,283	2,377	SH		2,030	A	Miocene	10,157
12	Repetto-Puente	Pli-Mio	1,960	475	SH		1,600	A	Miocene	5,084
13	Repetto-Puente	Pli-Mio	3,208	1,730	SH		900	A	Miocene	8,265
14	Repetto-Puente	Pli-Mio	5,100	3,350	SH		1,290	A	Miocene	7,048
15	Repetto	Pli	5,692	3,640	SH		395	AF	Miocene	8,376
16	Repetto-Puente	Pli-Mio	4,000	2,900	SH		500	A	Oligocene	10,496
17	Repetto-Puente	Pli-Mio	5,197	3,470	SH		1,570	A	Miocene	11,314
18	Repetto-Puente	Pli-Mio	5,369	4,314	SH		1,980	A	Miocene	9,054
19	Repetto-Puente	Pli-Mio	5,290	2,637	SH		150	A	Jurassic schist	6,597
20	Repetto	Pli	3,701	200	SH		250	MF	Miocene	5,040
21	Repetto-Puente	Pli-Mio	3,968	2,320	SH		2,000	AF	Schist	6,814
22										
23	Vaqueros-Sespe Monterey	Mio-Olig	2,736	1,150			350	A	Sespe	4,071
24	Vaqueros-Sespe	Mio-Olig	3,194	2,800			700	A	Sespe	7,157
25	Monterey	Mio	3,050	1,750	Broken shale		800	A	Vaqueros	6,510
26	Monterey	Mio	6,440	5,567	Broken shale					6,556
27	Repetto	Pli	5,751	4,800	SH		270	AF		7,291
28	Repetto	Pli	3,814	2,500	SH		650	A		7,449
29	Repetto	Pli	7,056	5,500	SH		775	AF	Pliocene	10,030
30	Vaqueros	Mio	2,053	1,965	SH		75	MF	Sespe	4,730
31										
32	Monterey	Mio	1,695	1,200	Broken shale SH		350	A		3,900
33	Sisquoc-Monterey	Pli-Mio	3,003	2,000	Broken shale SH		220	AN	Miocene	7,199
34	Monterey	Mio	4,462	4,000	Broken shale SH		210	MU	Franciscan	8,133
35	Monterey	Mio	2,711	2,200	SH			AF		4,310
36	Monterey	Mio	3,161	1,100	SH			A		5,815
37	Monterey and Vaqueros	Mio	830	400	SH		45	A		5,041
38	Repetto	Pli	9,088	3,450	SH		5,000	A		11,070
39										
40	Sespe-Eocene	Olig-Eoc	888 6,804 100	500 5,833 50	SH		900	A	Eocene	6,804
41	Monterey and Vaqueros	Mio	3,393	1,865	SH		600	MU		4,285
42	Pico	Pli	1,242	240	SH		160	MU		2,117
43			1,563							
44	Modelo-Vaqueros	Mio	1,745	1,500	SH					2,200
45	Modelo-Vaqueros	Mio	2,050	180	SH					
46	Modelo	Mio	1,566 6,787	1,290 6,160	SH			MU	Eocene	1,488 3,504
47	Modelo	Mio	1,613	858	SH		400	AF		3,445
48	Sespe	Olig	2,736	400	SH			AF		3,595
49	Sespe	Olig	1,910	602	SH		1,600	D	Eocene	7,423
50	Meganos	Eoc	1,213	1,100	SH			A		
51	Sespe	Olig	683	315	SH			MF		3,934
52	Sespe	Olig	3,385	2,200	SH		930	D	Eocene	6,702

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres: Oil	Total Oil Production, Bbl.: To End of 1938	Total Oil Production, Bbl.: During 1938
53	Sulphur Mt., *Ventura*	11	40		(3,663)
54	Topo-Eureka, *Ventura*	51	170		(10,760)
55	Temescal, *Ventura*	14	235		(270,748)
56	Timber Canyon, *Ventura*	40	110		(9,518)
57	Fresno-Lion Mt., *Ventura*	20	50		(20,739)
58	Torrey Canyon, *Ventura*	42	190		(49,835)
59	Wiley, Towsley Canyon, *Los Angeles*	51	28		(5,611)
60	*Other Coastal Counties*			1,159,862	42,273
61	Half Moon Bay, *San Mateo*	52	80		(1,715)
62	Sargent, *Santa Clara*	44	60		(8,740)
63	Edna, *San Luis Obispo*	28	200		(31,818)
64	Huasna, *San Luis Obispo*	9	60		0
65	Aliso Canyon			23,416	23,416
	San Joaquin Valley:				
66	Arvin, *Kern*	1⅓	260	23,963	22,496
67	Belridge, *Kern*	28	3,170	53,208,269	5,246,498
68	North, deep, *Kern*	8		(27,427,315)	(4,827,753)
69	North, shallow, *Kern*	27	(1,570)	(4,610,369)	(9,437)
70	South, *Kern*	28	(1,600)	(21,170,585)	(427,398)
71	Canal, *Kern*	1⅓	800	879,058	847,410
72	Coalinga, East, *Fresno*	38	14,767	215,409,265	1,720,698
73	Coalinga, West, *Fresno*	37		140,724,775	1,882,052
74	Coalinga, Eocene, *Fresno*	½	1,200	246,067	246,067
75	Edison, *Kern*	7	1,250	5,638,071	1,090,764
76	Elk Hills, *Kern*	20	7,647	146,000,299	3,877,508
77	Fruitvale, *Kern*	11	1,710	17,922,116	3,029,811
78	Greeley, *Kern*	2	1,600	1,694,784	1,163,723
79	Kern Front, *Kern*	26	2,450	40,823,178	3,046,164
80	Kern, River, *Kern*	38	10,432	273,343,753	931,607
81	Kettleman, Middle, *Kings*	7	200	524,727	19,273
82	Kettleman, North, *Kings and Fresno*	10	16,500	201,962,542	25,587,291
83	Lost Hills, *Kern*	29	2,450	47,459,989	1,274,649
84	McKittrick, *Kern*	41	1,565	88,353,692	1,264,193
85	Midway-Maricopa, *Kern*	37	37,900	857,695,348	22,864,748
86	Mountain View, *Kern*	5	1,890	31,862,501	3,970,954
87	Mount Poso, *Kern*	13	2,210	42,579,538	6,181,439
88	Premier, *Kern*	12	690	2,429,715	618,471
89	Rio Bravo, *Kern*	1½	1,200	2,071,953	1,944,120
90	Round Mountain, *Kern*	11	1,660	21,812,921	5,416,402
91	Tejon Ranch, *Kern*	2½	100	57,867	55,779
92	Ten Sections, *Kern*	2	1,500	3,593,574	2,472,682
93	Wasco, *Kern*	1	200	125,064	125,064
94	Wheeler Ridge, *Kern*	17	285	3,578,865	113,056
95	Coles Levee, *Kern*	⅙	*x*	10,347	10,347
96	Richfield Western, *Kern*	⅙	*x*	1,668	1,668
97	Total			5,156,685,862	248,877,331
	GAS FIELDS:		Gas		
98	Buena Vista Lake, *Kern*	4	1,000		
99	Buttonwillow, *Kern*	11	1,560		
100	Eureka, *Humboldt*	2	100		
101	McDonald Is., *San Joaquin*	3	1,060		
102	Goleto (Moore Ranch), *Sta. Barbara*	9	400		
103	Rio Vista, *Solano*	3	8,000		
104	Trico, *Kern*	4	1,080		
105	Sutter Buttes, *Sutter*	2	100		
106	Tracy, *San Joaquin*	3	350		
107	Semitropic, *Kern*	4	2,960		
108	Potrero Hills, *Solano*	½	100		
109	Total				

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells				Oil-production Methods at End of 1938			Pressure, Lb. per Sq. In.[d]		Character of Oil Approx. Average during 1938
				During 1938		At End of 1938	Number of Wells				Average at End of	Gravity A.P.I. at 60° F.
	To End of 1938	During 1938	Completed to End of 1938	Completed	Abandoned	Producing Oil[b]	Flowing	Pumping	Gas Lift	Initial	1938	Weighted Average
53						1		1				16
54						21		21				24
55				1		12		12				24
56						8		8				34
57						12		12				22
58						38		38				30
59						15		15				28
60												
61				1		2		2				42
62						9		9				18
63						13		13				14
64												12
65				1		1	1					22
66			2	0		2		2				30
67												37
68	168,439	41,579		21		55	49	2	4			
69						8	4	4	0			
70				4		114		114				22
71				12		15	15			3,600		36
72						92		92				17
73	1,136	20				593		593				16
74						9	9			3,200		32
75				2		88		88				18
76	84,607	632		2		169		169				27
77				18		173	14	159				20
78	9,726	8,144		7		15	11		4			32
79						399		399				13
80						992		992				14
81	13,547	628		0		3	3					50
82	1,209,548	114,624		30		219	96	6	117	3,150 4,500		38
83	with Belridge			5		270		270				24
84				5		205		205				17
85	337,809	14,479		33		2,555	2	2,553				18
86	41,018	3,831		3		177	3	169	5			30
87				18		249		249				15
88				1		79		79				14
89	901	901		23		24	24					39
90				35		129		129				16
91				0		2		2				23
92	7,967	2,900		25		26	26			3,600		34
93				2		3	3					39
94						29		29				25
95				1		1	1			4,200		49.0
96				1		1	1			3,600		44.5
97				954		13,853	1,052	12,481	320			
						Gas						
98	1,450	442		0		5						
99	9,588	2,703		0		30				1,260	840	
100				0		1						
101	5,433	4,279		1		6						
102	14,000			0		4						
103	4,861	3,624		6		19						
104	59	13				9						
105			2			2						
106	3,612	653				6						
107	1,044	328				24						
108				1		1						
109	5,272,310	362,012										

TABLE 1.—(*Continued*)

Line Number	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
53	Monterey	Mio	2,500		SH			ML		
54	Vaqueros	Mio	1,995	500	SH		700	A		2,956
55	Modelo	Mio	2,411	2,000	SH			AF		4,584
56	Repetto-Monterey	Pli-Mio	2,605	500	SH			MF		3,300
57	Monterey	Mio	1,744	844	SH			ML		
58	Vaqueros-Sespe	Mio-Olig	1,363	600	SH			AF		2,500
59	Modelo	Mio	808	600	SH			AF		3,835
60										
61	Purisima-Monterey	Pli-Mio	1,604	1,379	SH			ML		
62	Monterey	Mio	1,333	900	SH			ML		
63	Monterey	Mio	1,340	800	SH		400	S		4,424
64	Monterey	Mio	3,750	900	Broken shale			A		
65	Pico	Pli	5,365	4,795	S			ML		5,392
66	Chanoc	Pli	7,350	7,300	SH		50	MU	Granite	7,928
67										
68	Temblor-Vaqueros	Mio	8,323	1,917	SH	15	980	A	Eocene	9,492
69	Etchegoin-Temblor	Pli	5,457	2,600	SH		150	A		
70	Etchegoin-Temblor	Pli	875	1,600	SH		570	A		
71	Monterey-Stevens	Mio	8,259	8,340	SH	16	220	A		
72	Etchegoin-Temblor	Pli-Mio	2,091	1,860	SH		420	AUP		
73	Etch-Sta. Margarita	Pli-Mio	1,580	900	SH		420	MUP	Cretaceous	4,833
74	Tejon-Avenal	Eoc	6,893	6,400	SH	19	400	MU	Cretaceous	8,108
75	Kern River and Temblor	Pli-Mio	2,503	2,000	SH		80	ML, MI	Granite	
76	Etchegoin	Pli	3,119	3,450	SH		450	A	Miocene	8,404
77	Etchegoin-Chanoc	Pli	3,685	3,000	SH		900	AF	Sta. Margarita	6,879
78	Stevens-Vedder	Mio	7,996; 11,520	7,800; 11,396	SH		80; 40	NUF, AF	Lower Miocene	12,504
79	Etchegoin	Pli	2,180	1,700	SH		300	MF	Sta. Margarita	2,650
80	Kern River	Pli	838	400	SH		450	MU	Walker-Oligocene	4,852
81	Temblor	Mio	7,824; 8,271	7,563; 6,300	SH		337	A	Temblor	9,138
82	Temblor-Avenal	Mio-Eoc	10,846	10,600	SH	16	300	A	Eocene	11,746
83	Etchegoin	Pli	1,185	1,200	SH		80	AF	Vaqueros	7,858
84	Etchegoin	Pli	1,431	1,100	SH		90	MU	Temblor	6,664
85	Etchegoin-Maricopa	Pli-Mio	2,524	1,950	SH		100	MU	Temblor	9,735
86	Chanoc-Sta. Margarita	Pli-Mio	5,236	5,140	SH		100	MF	Temblor	8,419
87	Vedder	Mio	1,737	1,600	SH		90	MF	Granite	3,130
88	Etchegoin	Pli	2,784	2,577	SH		113	MF	Oligocene	6,070
89	Vedder	Mio	11,469	11,249	SH	25	260	A	Eocene	14,108
90	Temblor	Mio	2,018	1,600	SH		100	MF	Granite	3,763
91	Sta. Margarita	Mio	4,438	4,300	SH		40	AM	Basalt	6,986
92	Stevens	Mio	8,219	7,850	SH	20	614	A	Miocene-Monterey	8,984
93	Rio Bravo	Mio	13,175	13,096		15	108	A	Eocene	15,004
94	Etch.-Sta. Margarita	Pli-Mio	2,717	2,000	SH		1,000	A	Miocene	9,272
95	Miocene-Stevens	Mio	9,365			22	135	MU?		
96	Miocene-Stevens	Mio	8,677			20	195	MU?		
97										
98	Etchegoin	Pli	5,219	4,638	S			A		7,957
99	Etchegoin	Pli	2,750	2,500	S		20	D		4,946
100	Repetto	Pli	4,862	3,880	S			A		
101	Eocene	Eoc	5,216	5,178	S			A		5,298
102	Vaqueros	Mio	4,493	4,193	SH		354	AF		6,912
103	Eocene (Ione)	Eoc	4,300	4,129	S					7,029
104	Etchegoin	Pli	2,475	2,450	S					11,466
105	Chico	Cre	5,852	5,725	SH		90	MI		6,900
106	Cretaceous	Cre	4,885	3,920	S		30			7,000
107	Etchegoin	Pli	2,275	2,235	S		25	A		5,698
108	Upper Cretaceous	Cre	3,280		S		30			
109										

its F-1 well from a depth of 8965 ft. for 885 bbl. per day of 44° gravity oil from 130 ft. of sand (net) in the Stevens (Monterey) formation.

Richfield Western.—The Richfield Western field, about 3 miles northwest of the Ohio Oil Company's Coles Levee (F-1) and 1 mile east of the proved area of Elk Hills, in sec. 32-30-25, was discovered by the Richfield Oil Corporation when it completed its Tupman Western No. 1 well from a depth of 8677 ft., flowing 3018 bbl. per day of 44° gravity oil together with 18,000,000 cu. ft. of gas from 195 ft. of sand of the Stevens (Monterey) formation, which is productive in Ten Section field, approximately 4 miles northeast of this discovery.

It is the consensus that the Coles Levee and the Richfield Western discoveries are on the same structural feature, which is supposed to be an overlap or shore-line deposit along the flank of Elk Hills. If this is true, a field having a large areal extent has been discovered.

Wasco.—Continential Oil Co. discovered a new field in the Wasco district of Kern County when it brought in its K.C.L. No. 2-A, flowing 2900 bbl. of clean, 39.9° gravity, oil and 720,000 cu. ft. of gas per day from 83 ft. of formation between 13,092 and 13,175 ft. The original depth of the well was 15,004 ft., which is the deepest drilled hole in the world. Production is coming from Miocene formations. The gas-oil ratio of the well is very low and because of the great depth the flowing and gas-lift stages undoubtedly will constitute the productive life of the well. At present, two producers and three dry holes have been drilled in the field. Its maximum proved limits is estimated at 250 acres. Wells will be spaced one to each 40 acres. The discovery of the field is a technical triumph, but possibly an economic failure.

TABLE 2.—*Summary of Drilling Operations in California in* 1938

Important Wildcats Drilled in 1938

	County	Location			Total Depth, Ft.	Deepest Horizon Tested
		Sec.	Twp.	Rge.		
1	Los Angeles	14	4S	13W	7,788	Miocene
2	Los Angeles		4S	14W	5,275	Miocene
3	Fresno	18	20S	15W	6,853	Eocene (Avenal)
4	Kern	20	29S	26W	11,520	Miocene (Rio Bravo)
5	Santa Barbara	27	9N	33W	6,440	Miocene
6	Los Angeles	2	2S	12W	6,353	Miocene
7	Fresno	31	18S	13W	12,336	Eocene
8	Fresno	14	21S	15W	7,257	Eocene
9	Los Angeles	27	3S	16W	5,365	Pliocene
10	Kern	8	27	24	13,175	Eocene
11	Kern	10	31	25	9,365	Miocene
12	Kern	17	27	24	13,716	Eocene
13	Kern	7	27	24	13,129	Eocene
14	Kern	1	29	25	13,650	Eocene
15	Los Angeles	30	4S	12W	10,157	Miocene
16	Kern	32	30	25		Monterey (Miocene)

Coastal District

Las Flores.—The Standard Oil Co. made a new discovery adjacent to the old Cat Canyon field through the completion of its Las Flores Land No. 1 well for an initial of 800 bbl. of 16° gravity oil from a depth of 6404 ft., production coming from broken shale. The structure on which the well was drilled is a narrow asymmetric fold and it is entirely possible that the Cat Canyon field will be extended to this structure. The oil contains about 6 per cent sulphur and the well has been shut in since completion because there is no market for this type of crude.

Ventura Avenue.—Continued drilling activity in the Ventura Avenue field has resulted in increasing the productive depth of this structure to below 11,000 ft., giving the field over 7000 ft. of Pliocene producing horizon, with added reserves of over 20,000,000 barrels.

Los Angeles Basin

Aliso Canyon.—In the San Fernando Valley, near the location of California's first oil discovery in the year 1876, at Pico Canyon, the Tide Water Associated Oil Co. discovered the Aliso Canyon field. The prospect well, Porter No. 1, was drilled in sec. 27-3-16 and was completed flowing 850 bbl. of 23° gravity oil from a plugged depth of 5339 ft. The well was proposed to explore the Eocene sands of a well-defined anticline in the Monterey shale of Miocene age. It penetrated the flat-dipping Santa Susana fault of 1800 ft. and found production in 500 ft. of very porous sand in the Pico (Pliocene) formation. The extent or value of this discovery is as yet only a matter of conjecture.

Table 2.—(*Continued*)

Important Wildcats Drilled in 1938

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, M Cu. Ft.		Casing	Tubing	
1	Hildon Oil Co.	850	1,700	56/64	1,700	170	Discovery well, deep zone, Hildon area
2	D. B. Oil Co.	750	250	38/64	950	175	Discovery well, deep zone, Harbor City area, Torrance
3	Petr. Securities Co.	7,920	6,000	38/64	1,375	1,100	Discovery well, Coalinga Nose
4	Standard Oil Co.	14,852	3,000	1½ and 1	1,200	770	Deep zone discovery, Greeley field
5	Standard Oil Co.	808	0	Pump	75	70	Discovery well, Las Flores field
6	St. Helens Petr. Co.	990	7,134	7/8	1,350	600	Discovery West Extension Montebello
7	Pura Oil Co.	Dry hole					
8	Jacalitos Petr. Co.	Dry hole					Test of Jacalitos Dome
9	Tide Water Assn.	651	100	32/64	405	120	Discovery San Fernando field
10	Continental Oil Co.	2,900	720	open	800	625	Discovery well, Wasco field
11	Ohio Oil Co.	885	5,600	2¾	825	325	Discovery well, Coles Levee field
12	Standard Oil Co.	Dry hole					Dry hole, Wasco field
13	Standard Oil Co.	6,528	459	56/64	610	520	Second Producer, Wasco field
14	Superior Oil Co.	Dry hole					Deep test, Rio Bravo Oil Co.
15	De Soto Oil Co.	350	400	20/64	650	150	Discovery, new deep zone, Signal Hill
16	Richfield Oil Corp.	3,018	18,000	3–1½	1,000	1,000	Discovery well, East Elk Hills field

Extensions of Fields

Montebello.—The St. Helens Petroleum Co., Ltd., discovered two new zones (fifth and sixth) in the lower Pliocene and upper Miocene in the west portion of the Montebello field. Its well, Monterey No. 20, was completed flowing 990 bbl. of 36° gravity oil from a depth of 6353 ft. The Hathaway Oil Co. discovered a seventh zone in its Dore No. 1 well at a depth of 7181 ft. Upon completion this well flowed 400 bbl. of 35° gravity oil. Dore No. 1 well extended the Montebello field to the southwest. At the end of the year 30 wells were producing the newly discovered zones. Correlations with the zones developed in the East Montebello Extension indicates the possibility that several deeper zones are present in the west end of the field. The structural feature on the west end of Montebello is a plunging, asymmetrical nose. Edge water lies very close to the axis of each zone. The axis of each deeper zone lies progressively farther to the south. New reserves added to the Montebello field are estimated at 12,000,000 barrels.

Torrance.—The most active field in the state during 1938 was the Torrance, where development extended its areal limit to the south and southeast through the discovery of the Del Amo zone, which lies approximately 1300 ft. below the Upper or Main zone (3500 to 3800 ft.). The principal areas of development have been designated Lomita and Harbor City. Both are of a town-lot nature and production decline has been so rapid that it is questionable whether many of the operators will obtain the return of their investment, especially in the Lomita area. Completions have ranged between 100 and 600 bbl. per day and in numerous instances 600-bbl. wells have declined to 100 bbl. within two months. The producing horizon is an overlap on the Torrance uplift and the permeability of the sand, which averages 70 ft. in thickness, is very low. Like the early development of the upper measures, this new drilling is not expected to be very profitable.

Wilmington.—The Long Beach portion of this field was opened for drilling during the early part of the year and 200 wells were drilled. Very favorable results were obtained from Terminal zone wells, producing from as much as 1000 ft. of sand. With spacing of one well to the acre in the shore-line area, the peak of production was 125,000 bbl. a day in March. Drilling activity in the field is expected to continue during 1939, as there are as yet many undrilled locations. The Wilmington field is the only major oil field discovered in the Los Angeles Basin during the last eight years, and is considered to have reserves of approximately 200,000,000 barrels.

Rosecrans.—Prospecting of Miocene formations in this field during 1938 revealed the existence of an additional reserve of approximately 20,000,000 bbl. Wells completed below the 7000-ft. level have had

initials ranging from 500 to 2500 bbl. of 30° gravity oil. Faulting is the controlling factor of this deeper accumulation.

Signal Hill.—A deep test of the Signal Hill field was drilled during 1938 by the De Soto Oil Co. in the prolific Lovelady pool on the south flank of the structure. Initial production of the well was 250 bbl. of 28° gravity oil, which is coming from a depth of between 9760 and 10,157 ft. Considering its depth and small indicated potential, it is not a commercial well. The considerable sand thickness and unexpected gentle dips found in the Miocene at depth will probably be an incentive for further deep drilling during the coming year.

Summary

Activity in the oil industry depends, to a great extent, on general business conditions in the country; also, drilling activity depends on the rate of new discoveries, as older fields tend to be fully drilled or are in a state of depletion where new drilling is uneconomical. During 1937, fully 40 per cent of the drilling was in new fields discovered in 1936. In 1938, over 60 per cent of the wells drilled were in fields and extensions discovered in 1936 and 1937.

At the close of 1938, there was considerable anxiety in the industry regarding large additions to storage during the year. It is estimated that drilling activity during 1939 will be approximately 20 per cent less than in 1938, owing mainly to a scarcity of proved locations and tendency toward more conservative well spacing.

TABLE 3.—*Activities in California Petroleum Industry*

Year	Number Drilling Notices Filed	Number Drilling Wells Abandoned	Number Producers Completed	Increase or Decrease over Previous Year, Per Cent	Initial Production on New Wells, Daily Average, Bbl.	
					Per Well	Total
1929	1,256	314	910		1,437	1,307,496
1930	918	254	755	−17	775	584,521
1931	329	238	246	−67	1,481	364,434
1932	279	191	184	−25	852	156,823
1933	596	163	248	+35	1,105	274,104
1934	631	247	449	+81	1,190	534,508
1935	986	347	710	+37	954	677,320
1936	1,102	320	786	+11	471	370,227
1937	1,643	313	1,156	+47	560	647,331
1938 (est.)	1,180	220	987	−14	1,215	1,200,000

Oil and Gas Development in Colorado in 1938

By C. E. Shoenfelt,* Member A.I.M.E.

The outstanding development in Colorado in 1938 was the completion of the discovery well of the Wilson Creek structure in Rio Blanco County, on the western slope in the northwest corner of Colorado. Last year

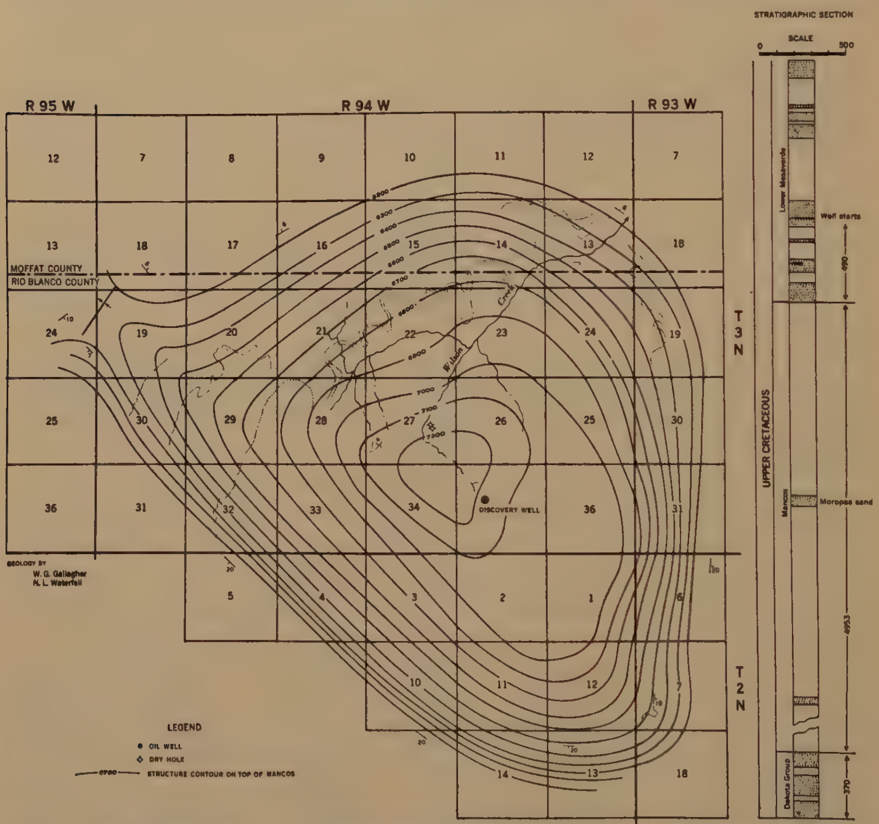

Fig. 1.—Structure map and stratigraphic section, Wilson Creek dome, Rio Blanco County, Colorado.

the Transactions (volume 127) carried an account of the discovery of oil in the Morrison sand in the Wilson Creek structure, in the joint test by The Texas Company and The California Company. This important

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discovery well (Fig. 1) was not completed until February 1938, although it had found oil saturation, as previously reported, in Morrison sand at 6664 to 6704 ft., and on drill-stem test had produced at the rate of 62 bbl. of oil an hour. In January 1938, the well was drilled through the Sundance sand at 6824 to 6898 ft., where it encountered water. It was then plugged back to the Morrison where, on a 24-hr. open-flow test through 2½-in. tubing, it produced 492 bbl. of 46° A.P.I. gravity, paraffin-base oil. During the remaining months of 1938, beginning with July, the Wilson Creek well produced 60,150 bbl. of oil, most of which was delivered by truck to The Texas Company's refinery at Craig.

Wilson Creek has had two previous tests, neither of which was drilled into the Sundance section. The first well, on SE. NW. SE. of sec. 27-3 N-94 W, was drilled by the Richmond Petroleum Co., a subsidiary of the Standard Oil Company of California, and was abandoned at a depth of 4826 ft. It did not reach the Dakota. The second well, drilled by The Texas Production Co., on about the same location, was abandoned after encountering water in the Dakota sand at 5863 to 5913 ft. Both of these wells had minor showings of oil in Upper Cretaceous sands.

TABLE 1.—*Oil and Gas Production in Colorado in* 1938

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					Oil-production Methods at End of 1938	
										During 1938		At End of 1938		Number of Wells	
			Oil	Gas[a]	To End of 1938	During 1938	To End of 1938	During 1938	Completed to End of 1938	Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Flowing	Pumping
1	Berthoud, *Larimer*	9	510		50,342	4,200	5,747	583	6			1	1		3
2	Boulder, *Boulder*	36	400		639,062	7,023			55		1	11			8
3	Florence, *Fremont*	77	9,000		13,465,658	62,843			1,203	1		105			106
4	Ft. Collins, *Larimer*	15	400		2,090,239	33,105			15			7			6
5	Garcia, *Las Animas*	12		640			31,353	543	16		1		6		
6	Greasewood, *Weld*	8	200		448,328	8,691			8			1			1
7	Hamilton, *Moffat*	15	400		5,450,222	118,966			23			12			12
8	Hiawatha, *Moffat*	11		3,180			159,418	13,153	10				9	1	
9	Iles, *Moffat*	14	600		7,201,117	818,822			39	3		34		15	17
10	Mancos Creek, *Montezuma*		40						33						
11	Model, *Las Animas*	10		4,380			645[2]	0	8						
12	Rangely, *Rio Blanco*	19	320		448,645	26,084			52			5			6
13	Thornburg, *Rio Blanco*	14		350			1,569	777	3				3		
14	Tow Creek, *Routt*	14	200		1,591,450	56,900			17			15			5
15	Walden, *Jackson*	11	320		156,886	0[1]			5		1				
16	Wellington, *Larimer*	14	1,000		4,702,847	76,416			32			11			11
17	Price, *Archuleta*	4	200		337,193	176,173			20		1	9			10
18	Wilson Creek, *Moffat*	1	160		50,149	50,149			1	1				1	
19	Total		13,750	8,550	36,632,138	1,439,372	198,732	15,056	1,546	5	4	211	19	17	185

[a] Footnotes to column heads and explanation of symbols are given on page 240.
[1] Wells produce large quantities CO_2 gas with the oil—shut in.
[2] Inert: contains 7.9 per cent helium.

Wilson Creek is a large circular dome along the Danforth Hills line of folding and has fully 1000 ft. of structural closure. The lowest closing contour embraces roughly 15,000 acres.

The Hiawatha gas field entered the list of producing oil fields in 1938. The presence of oil in small quantities in lenticular sands in the Wasatch formation has been known for a number of years, but no effort to develop oil production was made until last October, when the Mountain Fuel Supply Co. worked over its No. 1 Kuykendall, NE. NE. SE. of sec. 22-12 N.-100 W., and perforated casing with a Lane-Wells gun between 2472 to 2483 ft. After a short swabbing test, the well was put to pumping, and over a 60-day period averaged 80 bbl. of oil a day. The oil is found in sandy shale and has an A.P.I. gravity of 47°. It has a high gasoline yield and will prove a valuable refining crude if it can be obtained in quantity. The No. 1 Kuykendall well was one of the early completions at Hiawatha and had an initial production of 37,000,000 cu. ft. of gas a day from a sand lens in the Wasatch formation at 1992 to 2025 ft. In 1935, this well was deepened to 2812 ft. and in 1936 was plugged back to 2495 ft. where the $4\frac{3}{4}$-in. pipe was cemented and the well shut in.

TABLE 1.—(*Continued*)

	Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1938	Producing Formation								Deepest Zone Tested to End of 1938	
		Average at End of		Gravity A.P.I. at 60° F.			Depth, Average in Feet							
Line Number	Initial	1937	1938	Weighted Average	Name	Age[e]	Bottoms of Productive Wells	To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
1	600	90	80	38.5	Hygiene	CreU	2,940	2,920	S	20	20	A	Lakota (CreL)	4,031
2				38.6	Pierre	CreU		2,000	H			MF	Morrison (Jur)	3,497
3				31	Pierre	CreU		2,200	H			TS	Fountain (Pen)	1,875
4				34.8	Muddy-Dakota	CreU	4,560	4,535	S	12	25	A	Dakota (CreU)	4,995
5	12	4	4		Benton	CreU		1,600	H			D	Morrison (Jur)	1,392
6				42	Muddy	CreU			S	9	35	A	Morrison (Jur)	7,040
7				41	Dakota	CreU	3,880	3,860	S	18				
					Sundance	Jur			S	14	20	D	Sundance (Jur)	4,490
8					Wasatch	Eoc	Sand	lenses	S	*y*	*x*	D	Mesa Verda (CreU)	7,577
9				37	Sundance	Jur	3,315	3,295	S	9	20	D	Sundance (Jur)	3,447
10				40	Mancos	CreU		375	S	*y*	*y*	ML	Dakota (CreU)	1,280
11	12	Shut in			Santa Rosa(?)	Tri	1,004	960	S	19	50	D	Fountain (Pen)	2,010
12					Mancos	CreU		600	H			A	Mississippian	7,173
					Dakota				S	15	35		Sundance (Jur)	3,095
13	725	″	″		Sundance	Jur	2,125 3.050	1,975 2,525	S	15	500	D	Sundance (Jur)	3,110
14				35	Mancos	CreU		2,600	H			A	Gneiss[8]	5,310
15				50	Muddy-Dakota	CreU	5,215	5,110	S	14	90	AF	Morrison (Jur)	5,258
16				37.4	Muddy-Dakota	CreU	4,500	4,480	S	12	20	A	Sundance (Jur)	4,992
17				40	Dakota	CreU	1,140	1,120	S	*y*	*y*	A	Dakota (?)	
18				46	Morrison	Jur	6,704	6,664	S		40	D	Sundance (Jur)	6,898
19														

[8] Oldest sedimentary formation tested Thaynes (Triassic).

One or two of the old gas wells at Hiawatha have produced small quantities of oil in gas-line drips, and in 1934, the Mountain Fuel Supply Co. completed its No. 4-B Florence Wilson, C. NE. NW. of sec. 23-12 N.-100 W., for 20 bbl. of oil a day at 2345 ft. after plugging back from 3797 feet.

It now seems probable that a small oil field will eventually develop at Hiawatha, but enough wells have been drilled to prove that such a field would not be of major importance. Its greatest drawback, for a small field, is its distance from railroad and therefore from a satisfactory market.

In eastern Colorado, only one important wildcat was drilled to completion and it proved a disappointment after having had an encouraging showing of oil. This failure was an operation of the Gulf Oil Corporation, No. 1 Union Pacific-Larsen on the C. SE. NW. of sec. 13-13 S.49 W., near Mount Pearl in Cheyenne County. This well was abandoned in pre-Cambrian schist at 6360 ft. after the showing of oil in Kansas City lime at 4808 to 4813 ft. had proved noncommercial. The following "tops" were determined in the laboratory of Petroleum Information, Inc.:

Feet		Feet	
0– 100	Tertiary and windblown sands	2790	Top of Triassic
100– 960	Pierre shale	3210	Top of the Cedar Hills
960–1550	Apishapa shale	3275	Top of the Harper
1550–1630	Timpas lime	3365	Top of the Cimarron
1630–1640	Codell sand	4220	Top of the Pennsylvanian
1640–1800	Carlile shale	4270	Top of the Shawnee
1800–1885	Greenhorn lime	4610	Top of the Kansas City
1885–2020	Graneros shale	4785	Top of the Marmaton
2020–2220	Dakota sand	5265	Top of the Cherokee
2220–2360	Purgatoire shale	5669	Top of the Morrow
2360–2380	Lytle (Lakota)	5719	Top of the Mississippi
2380	Top of the Morrison	5923	Top of the Arbuckle
2690	Top of the Todilto	6292	Top of Cambrian sand
2750	Top of the Exter	6360	Top of pre-Cambrian; total depth
		4518	Elevation

The test of the Divide Creek anticline in SW. SW. NW. of sec. 36-8 S.-91 W., in Mesa County was one of the important operations still in progress at the end of the year, although shut down for the winter. This well, No. 1 David B. Miller, which has a surface elevation of 9395 ft., had reached a depth of 9410 ft. when operations were suspended on Dec. 3, 1938. It is on the side of a mountain at the head of Mosquito Creek, a tributary of West Divide Creek. The country is rough and heavily timbered. Before the construction of the road into the location, part of which has a grade of 17 per cent, access was by horseback or on foot only. During muddy weather, in the early spring especially, material is hauled in by caterpillar tractors. This is the second winter that operations have been suspended, as the well was started late in 1937.

The structure on which this test is located is a long anticlinal fold of about 1900 ft. of closure with 15,000 acres inside the closing contour. The length of the fold totals nearly 25 miles. Rocks of Wasatch (Tertiary) and Mesaverde (Cretaceous) age form the surface, the former occupying the highest topographic points and the flanks, while the latter are exposed for a considerable area along the crest.

The well is at the head of a sharp valley about 800 to 1000 ft. below the Wasatch-Mesaverde contact. The Wasatch formation lies unconformably on the Mesaverde. It reached the base of the Mesaverde formation at 3980 ft. and at 9410 ft. is still in the underlying Mancos shale. No markers have been encountered since passing through a sandstone, possibly the equivalent of the Morapos, at 4935 to 4945 ft., and a considerably greater amount of Mancos shale has been penetrated than was anticipated.

Steep dips, which increased to 41° and gradually decreased downward, were first encountered at 5400 ft. The dip for the last several hundred feet has been about 3°. Polished faces on fracture planes were taken out in cores at about 6600 ft. in shale. A great deal of the shale has contained siltstone layers and streaks up to a few inches in thickness, and many of these showed an odorless gas under high pressure when first brought out.

Operations will be resumed in the spring as soon as the location is accessible. The test is being drilled jointly by the Continental Oil Co., The California Company and Amerada Petroleum Corporation. Electric power is used, which is supplied by Diesel motors and generators.

The Morapos Petroleum Co., jointly with MacKinnie Oil & Drilling Co., is drilling an interesting test on Morapos structure in Moffat County, on the northwest side of the dome in an area believed to hold possibilities of obtaining oil production in the Sundance sand. Higher on the structure, a well drilled by Continental Oil Co. was a failure in the Sundance but Ross L. Heaton, who is responsible for the original geological work on the structure, believes the site selected for the present drilling well is favorable for oil because the shales that are the source of oil in the Iles field thicken rapidly to the north and should have a satisfactory development in the neighborhood of the drill site.

The present operation is known as No. 1 N. E. Coles and is located on the SW. SW. SE. of sec. 1-3 N.-92 W. The well was spudded on May 1, 1937, and at the end of 1938 had attained a depth of 3075 feet.

Samples from this well have been examined in the laboratory of Petroleum Information, Inc., since the well began spudding. It had the top of the Frontier at 2468 ft., the top of the Dakota at 2870 ft., and top of the Morrison at 3017 ft. As the Morrison has an average thickness of 300 ft. in this part of Colorado, the Coles wells should have the top of the Sundance formation at about 3320 feet.

The Garcia anticline in southern Colorado was tested into the Fountain formation in 1938, with a well drilled by the Garcia Corporation on the McClung farm in the NE. NW. SE. of sec. 19-33 S.-61 W. This well was abandoned at 2500 ft. without developing any showings of oil or gas.

The crest of the Garcia structure has a general northeast-southwest trend, with its highest point in sec. 19-33 S.-61 W., and it plunges to the southwest. The actual closure of the structure will not exceed 150 ft., but this closure may be augmented by a large vertical dike of basalt, which cuts the fold a little northeast of its crest. Although this dike is the only one that has been traced continuously across the area, other dikes are known to exist and may be more continuous than is indicated by their exposed outcrops. The extensive dike system of this part of Colorado radiates out of the Spanish Peaks, 30 miles to the west. A few dikes, notably those near Trinidad, are younger than the Spanish Peaks system. They radiate out of the Raton Mesa and cut the dikes of the Spanish Peaks system. Other dikes of the Raton Mesa system in the vicinity of the Garcia anticline, cut beds of Upper Cretaceous shales, notably Pierre and Apishapa, out of which they have baked oil and which may now be found in vesicular cavities in the basalt. Both dike systems are younger than the Nussbaum formation, which is of late Eocene age.

The Garcia anticline is partly developed and is productive of gas, with a high gasoline content, from wells completed in sandy phases of the Pierre and Apishapa shales. The wells have low initial capacities but are long-lived. One well, over 30 years old, supplies a near-by ranch house with fuel. The best wells are at points along the anticline where there is a flattening of the dip. Wells high on the structure near the crest are barren in the shales. The Dakota sands and the basal Morrison sand, the Exter, are water-bearing.

The possibilities of obtaining oil in any part of the Garcia anticline are remote. The Dakota sand and other Cretaceous sands rise rapidly to the east and may be traced almost continuously around the area by their exposed outcrops. They are the source of water in drilled wells. Beds below the Cretaceous do not offer a favorable source for oil.

Acknowledgment

The information contained in this report was obtained from weekly and monthly reports published during the past 11 years by Petroleum Information, Inc., of Denver.

Oil and Gas Development in Illinois in 1938

By Alfred H. Bell,* Member A.I.M.E.

(New York Meeting, February, 1939)

The upswing in oil production and drilling activity in Illinois that began in 1937 gained momentum in 1938 and promises to bring a new and higher peak in the state's annual production in 1939. In 1938 the production totaled 23,929,000 bbl., as compared with 7,426,000 bbl. in 1937, more than a threefold increase. The number of producing oil wells in the new fields was 230 at the end of 1937 and it increased to 2157 at the end of 1938. Daily production for the whole state increased from approximately 35,000 bbl. at the end of 1937 to approximately 135,000 bbl. at the end of 1938, nearly a fourfold increase.

Of a total of 2539 wells completed in 1938 in Illinois, 1984 produced oil, 26 produced gas and 529 were dry holes. Of the total, 377 are classified as "wildcat" wells, defined as wells drilled outside of proved territory and more than one mile from the nearest production. The remainder, 2162 wells, were drilled in or near proved fields.

Of the 377 wildcat wells (Table 2) 32 were successful in discovering oil or gas in commercial quantities, either new fields or extensions of old fields. Four of these discovery wells were gas wells, which are not yet commercially productive owing to lack of pipe-line facilities.

A special effort was made to ascertain the reasons for the locations of as many as possible of the wildcat wells and the results of this investigation are set forth in the following table:

Reason for Drilling	Total Number	Successful	Per Cent
Geology	30	9	30
Geophysics	14	4	29
Geology and geophysics	25	12	48
Total, scientific	69	25	36
Geologic information available, but not favorable	9	0	0
Not based on geologic or geophysical information	91	3	3
Unknown	208	4	2
	377	32	8.5

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There is a striking contrast between the percentage of successes of the locations made with and without scientific aid; 36 per cent as against 3 per cent. Although this preponderance in favor of the scientifically made locations would probably be reduced somewhat if complete data were available, there is little doubt that the great majority of the 208 wildcat locations for which the data could not be obtained were made

Fig. 1.—Oil and gas fields in Illinois in 1938.

without benefit of either geologic or geophysical recommendations, probably, in many cases, to fulfill contracts.

Economic Data

Exact data on value at the wells of the crude oil produced in Illinois in 1938 are not at hand. Posted prices were as follows:

	Price per Barrel
Old fields:	
January 1–September 27	$1.35
September 27–October 13	1.25
October 13–December 31	1.05
New fields:	
January 1–May 25	1.35
May 25–October 1	1.25
October 1–December 31	1.15

On the basis of posted prices, the total value of the 1938 production was approximately $29,300,000. Dividing this by the number of barrels of

oil produced, it is calculated that the average price per barrel for the year was $1.22. However, it is reported that considerable quantities of oil in some fields were sold below the posted price, therefore it may be assumed that the total returns from the oil were less than the total mentioned above.

No exact data are available as to drilling costs. A total of 4,766,047 ft. of hole was drilled in the state in 1938. If an average cost for all drilling in the state is assumed to be $3 per foot, it is calculated that there was a total investment in drilling of $14,298,141. This includes both producing wells and dry holes. There were, of course, large additional investments in leasing, equipping and operating wells, in storage tanks, pipe lines, warehouses, etc., for which even an approximation is not possible at this time.

The average depth of all wells drilled in the state in 1938 was 1870 ft. and the average initial daily production of the oil wells was 274 bbl. (For details see Tables 3 and 4.)

Pipe Lines and Refineries

Although the new oil reserves of Illinois enjoy the advantage of close proximity to a large market for refined products, the disposal to refineries of the rapidly increasing amounts of crude oil produced has presented some problems. These have been met in part by the construction of new pipe lines and substantial quantities of oil have been transported by rail and truck.

There has been a considerable amount of "pipe-line proration"; that is, curtailment of production by oil buyers, notably in the Centralia and Louden fields. There is no regulation of oil production in Illinois by any State authority.

The new Central States pipe line (Texas Company subsidiary) extends from the Salem field to the Indian Refinery at Lawrenceville (Fig. 1). It was put in operation on Nov. 14, 1938. It furnishes sufficient oil to run the refinery, and the surplus oil is transported north through the old Texas-Empire branch pipe line, which joins the main line at Heyworth (south of Bloomington, McLean County). From there the oil goes north to the Texas Company's refinery at Lockport, and other refineries in the Chicago district.

The Magnolia Petroleum Co. transports oil from the Salem pool to East St. Louis via Sandoval, Vandalia and Wood River.

Three small refineries were constructed at Centralia (capacity 2000 bbl. per day each) and one at St. Elmo (capacity 3500 bbl.).

The oils from the new Illinois fields range in gravity from 37° to 39° A.P.I., averaging approximately 38°. Sulphur content ranges from 0.12 to 0.18 per cent. These oils are similar to Mid-Continent crudes in their general characteristics (Table 1).

Exploration Methods

The principal methods used in guiding exploration and development are subsurface geology and geophysics, largely the reflection seismograph. Nearly 100 petroleum geologists are now making investigations of Illinois geology. Use is made of driller's logs, drilling-time logs, sample and core studies, electrical logs, and micropaleontology. Some of the oil companies are depending on electrical logs to make structural studies and correlations in fields because they are more quickly made than sample study logs. However, there appears to be no substitute for sample studies in attacking the regional problems of stratigraphy, sedimentation and structure.

The extent of reflection seismograph surveys for 1938 in Illinois is indicated by the following figures:

Date	Number of Seismograph Parties Active in Illinois
January 1, 1938	11
April 1, 1938	9
July 1, 1938	7
October 1, 1938	16
January 1, 1939	11

During the year approximately 196 townships (7056 square miles) were covered by seismograph surveys, mostly in the Illinois Basin.

Other geophysical methods, notably gravimeters and magnetometers, are being used to a relatively small extent and a few companies are engaged in structure test drilling.

The course of development during 1938 and the last eight months of 1937 is illustrated in the bar chart showing production by months (Fig. 2). Total lengths of the bars represent monthly production for the whole state. The bars are divided into old fields (stippled) and new fields (shaded): dark shading, limestone production, and light shading, sandstone production.

The limestone production is almost all from the "McClosky sand," which is a porous, oölitic zone in the Fredonia member of the Ste. Genevieve formation (Fig. 3). The McClosky production had its most rapid rise during the summer of 1937. The wells had large initial productions, but they also had rapid declines during the first few months. Average depth of the McClosky wells in the central part of the basin is approximately 3000 ft. (Table 1).

Development in 1938 consisted largely of the development of the comparatively shallow sandstone fields in the western part of the Illinois Basin where production is obtained from depths varying from 1300 to 1800 ft. The principal producing sands are the Cypress (called variously Carlyle, Stein, Weiler and Kirkwood) and the Benoist (Bethel formation) called Tracy in Lawrence County. The three most important fields in

this region are the Salem (Lake Centralia), the Louden (Beecher City), and the Centralia. Daily production of these wells at the end of 1938 was: Salem, 50,300 bbl., an average of 105 bbl. per well; Louden, 22,000 bbl., average 44 bbl. per well; Centralia (New), 7500 bbl., average 14 bbl

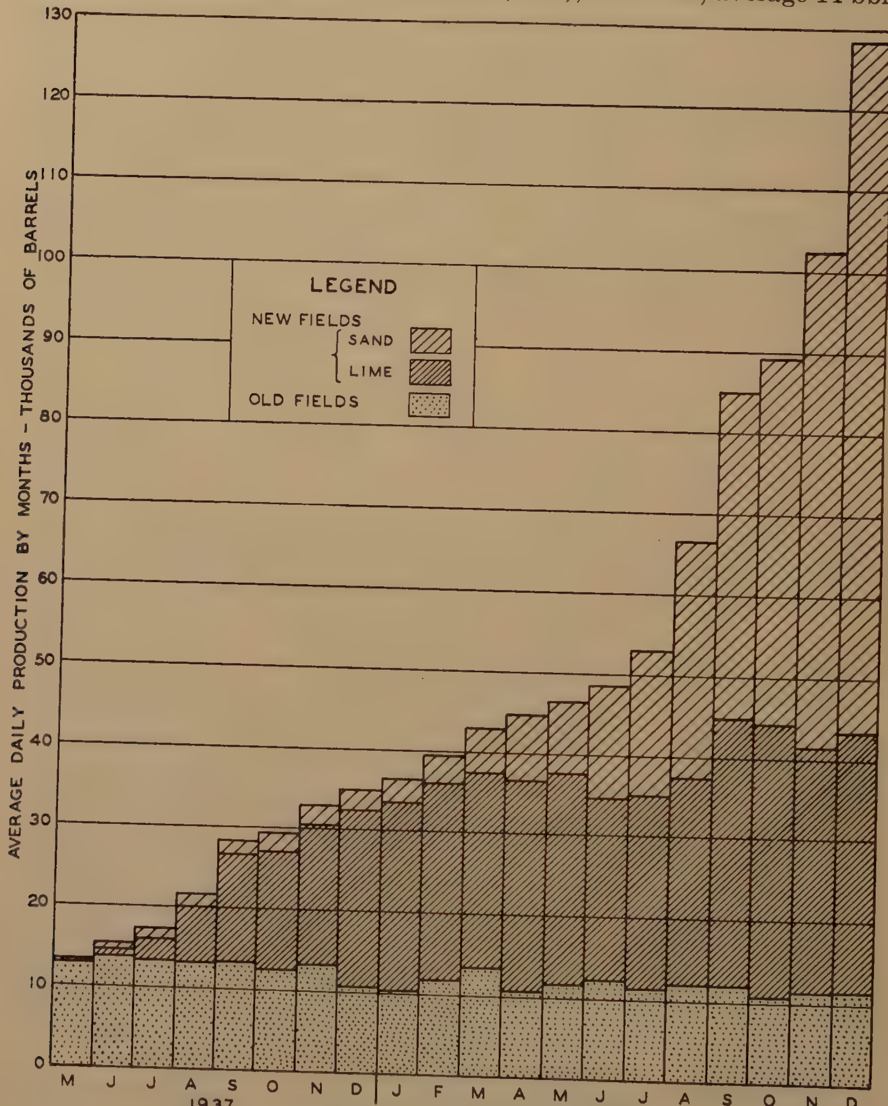

FIG. 2.—PRODUCTION OF CRUDE OIL IN ILLINOIS.

per well. Other details are given on lines 90, 84 and 94, respectively of Table 1. The Louden (Beecher City) and Centralia fields were discovered late in 1937, but had their major development in 1938. Centralia was outlined by early summer and was nearly completely drilled up by

the end of the year. Louden (Beecher City), on the other hand, was less than half developed at the end of 1938. Salem has had a remarkably rapid development; its discovery well was completed July 6, and it bids fair to outrank the best of the old fields—Lawrence County—in yield per acre.

Numerous new McClosky lime discoveries were made in the latter half of 1938. Of these, the North Aden pool in Wayne County appears to be the most important. For a detailed statement of wells and drilling operations in the new fields at the end of 1938 see Table 5. Data on discovery wells are given in Table 6.

Drilling to Devonian and Deeper

Fifty-three wells reaching the Devonian limestone or deeper were completed in Illinois in 1938. Of these, two discovered oil in commercial quantities in the Devonian; one was a small gas well in the Pennsylvanian; one was the discovery well for Benoist production in the Dix pool, Jefferson County; five were Trenton lime producers in the Dupo field, St. Clair County; one was a small Hoing sand producer in the Colmar-Plymouth field, McDonough County; and the remainder were dry holes. Five of these wells reached the St. Peter sandstone, which is correlated with the Wilcox sand of Oklahoma. The St. Peter sandstone has not yet yielded any oil in Illinois.

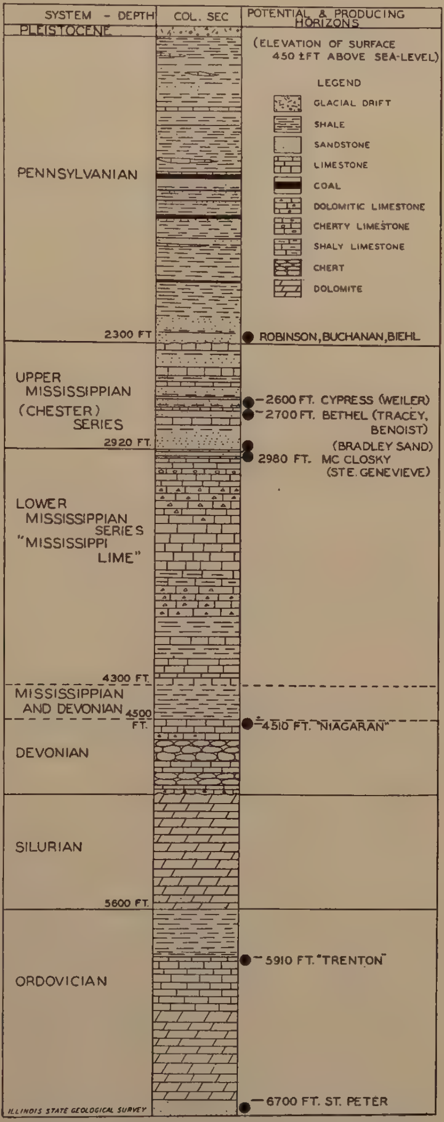

Fig. 3.—Generalized geologic column, Illinois Basin fields in Clay, Richland and Wayne Counties.

Oil in commercial quantity was recently discovered in the Devonian limestone at a depth of 2920 ft. in the old Sandoval field, which has been producing for 30 years from the Benoist sand at an average depth of

1550 ft. This is especially significant because it suggests the possibility of extensive Devonian oil on favorable structures in the Illinois Basin. Some of these—for example, the Louden (Beecher City) and Salem (Lake Centralia) structures—are known to be much larger than the Sandoval structure.

TABLE 1.—*Oil and Gas Production in Illinois in* 1938

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres: Oil	Area Proved, Acres: Gas[a]	Total Oil Production, Bbl.: To End of 1938	Total Oil Production, Bbl.: During 1938	Total Gas Production, Millions Cu. Ft.: To End of 1938	Total Gas Production, Millions Cu. Ft.: During 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Producing Oil[b]	At End of 1938: Producing Gas[c]
1	Warrenton-Borton, *Edgar*	32	100	0	29,030±	630	0	0	22	0	0	13	0
2	Westfield (Parker Twp.), *Clark, Coles*	34	9,000	55	*x*	*x*	*x*	0	1,621	5	40	332	0
3			850	75	*x*	*x*	*x*	0	185	0	0	*y*	0
4			9,000	0	*x*	*x*	*x*	0	1,443	5	0	*y*	0
5			1,500	0	*x*	*x*	*x*	0	12	0	0	*y*	0
6	Siggins (Union Twp.), *Cumberland, Clark*.....	32	3,580	75	*x*	*x*	*x*	0	995	0	0	914	0
7			3,135	55	*x*	*x*	*x*	0	854	0	0	*y*	0
8			435	15	*x*	*x*	*x*	0	90	0	0	*y*	0
9			855	105	*x*	*x*	*x*	0	192	0	0	*y*	0
10	York, *Cumberland*.......		310	40	*x*	*x*	*x*	0	70	0	0	44	0
11	Casey, *Clark*............	31	1,925	55	*x*	*x*	*x*	0	532	0	0	471	0
12			190	15	*x*	*x*	*x*	0	41	0	*y*	*y*	0
13			400	0	*x*	*x*	*x*	0	82	0	*y*	*y*	0
14			1,525	15	*x*	*x*	*x*	0	319	0	*y*	*y*	0
15	Martinsville, *Clark*......	31	710	155	*x*	*x*	*x*	0	213	0	4	122	0
16			15	20	*x*	*x*	*x*	0	7	0	0	*y*	0
17			275	35	*x*	*x*	*x*	0	63	0	0	*y*	0
18			105	0	*x*	*x*	*x*	0	21	0	0	*y*	0
19			170	0	*x*	*x*	*x*	0	34	0	0	*y*	0
20			195	0	*x*	*x*	*x*	0	39	0	0	*y*	0
21			5	0	*x*	*x*	0	0	1	0	0	1	0
22	North Johnson, *Clark*....	31	1,320	20	*x*	*x*	*x*	*x*	485	0	0	448	0
23			1,115	0	*x*	*x*	*x*	*x*	296	0	0	*y*	0
24			160	0	*x*	*x*	*x*	*x*	32	0	0	*y*	*y*
25			820	5	*x*	*x*	*x*	*x*	177	0	0	*y*	0
26			215	0	*x*	*x*	0	0	44	0	0	*y*	0
27	South Johnson, *Clark*....	31	1,715	65	*x*	*x*	*x*	*x*	534	0	0	486	0
28			185	5	*x*	*x*	*x*	*x*	38	0	0	*y*	0
29			295	0	*x*	*x*	*x*	*x*	59	0	0	*y*	0
30			1,675	35	*x*	*x*	*x*	*x*	401	0	0	*y*	0
31			845	5	*x*	*x*	*x*	*x*	170	0	0	*y*	0
32	Bellair Crawford, *Jasper*.	31	1,300	5	*x*	*x*	*x*	*x*	485	0	0	403	0
33			1,165	0	*x*	*x*	*x*	*x*	309	0	0	*y*	0
34			315	0	*x*	*x*	*x*	*x*	63	0	0	*y*	0
35			910	0	*x*	*x*	*x*	*x*	182	0	0	*y*	0
36	Clark County Division[1]		19,960	475	52,105,000±	193,000	*x*	*y*	4,982	5	44	3,234	0
37	Main,[2] *Crawford*.........	32	35,135	515	*x*	*x*	*x*	*x*	7,322	3	38	5,193	0
38			340	0	*x*	*x*	*x*	*x*	68	0	*y*	*y*	0
39			33,795	510	*x*	*x*	*x*	*x*	7,141	0	0	*y*	0
40			1,000	0	*x*	*x*	*x*	*x*	108	0	*y*	*y*	0

[a] Footnotes to column heads and explanation of symbols are given on page 240.
[1] Total of lines 1, 2, 6, 10, 11, 15, 22, 27, 32.
[2] Includes Kibbie, Oblong, Robinson and Hardinsville.

TABLE 1.—(*Continued*)

Line Number	Oil-production Methods at End of 1938: Number of Wells: Flowing	Pumping	Air, Gas, Water Lift	Pressure, Lb. per Sq. In.[d22]: Initial	Average at End of: 1937	1938	Character of Oil, Approx. Average during 1938: Gravity A.P.I. at 60° F.[23]: Weighted Average	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
1	0	13		x	x	x	x	Unnamed	Pen	215	159	S	Por	x	ML	Pen	715
2	0	332		200±	x	x	34.0	See below							D	Trenton	2,918
3	0	y		x	x	x	30.0	Shallow gas sand	Pen	376	281	S	Por	36	D		
4	0	y		x	x	x	33.5	Westfield lime	MisL	446	334	L	Cav	x	D	St. Peter	3,009
5	0	y		x	x	x	37.0	Trenton (Ord)	Ord	2,568	2,265	L	Por	x	D		
6	0	914	24	x	x	x	33.0	See below							D	Dev. limestone	2,010
7	0	y		x	x	x	34.0	First Siggins sand	Pen	465	367	S	Por	x	D		
8	0	y		x	x	x	(33.6)	Second and third Siggins sand	Pen	562	478	S	Por	x	D		
9	0	y		x	x	x	(25.7)	Lower Siggins sand	Pen	590	556	S	Por	x	D		
10	0	44		x	x	x	(30.3)	York sand	Pen	680	588	S	Por	x	AM		960
11	0	471	25	x	x	x	29.2	See below							AM	MisL	808
12	0	y		x	x	x	(31.9)	Upper gas sand	Pen	358	263	S	Por	x	AM		
13	0	y		x	x	x	(30.1)	Lower gas sand	Pen	426	309	S	Por	x	AM		
14	0	y		x	x	x	(33.6)	Casey sand	Pen	505	444	S	Por	x	AM		
15	0	122		x	x	x	36.8	See below							D	St. Peter	3,411
16	0	y		x	x	x	y	Shallow sands	Pen	411	255	S	Por	x	D		
17	0	y		x	x	x	y	Casey sand	Pen	511	449	S	Por	x	D		
18	0	y		x	x	x	y	Martinsville	MisL	506	477	L	Por	x	D		
19	0	y		x	x	x	(38.9)	Carper	MisL	1,418	1,340	S	Por	x	D		
20	0	y		x	x	x	y	"Niagaran"	Dev	1,596	1,553	L	Por	x	D		
21	0	1		x	x	x	(39.6)	Trenton	Ord	2,830	2,708	L	Por	x	D		
22	0	448		x	x	x	31.0	See below							AM	Mis	965
23	0	y		x	x	x	y	Claypool sand	Pen	486	416	S	Por	x	AM		
24	0	y		x	x	x	y	Shallow sands	Pen	451	314	S	Por	x	AM		
25	0	y		x	x	x	y	Casey sand	Pen	508	465	S	Por	x	AM		
26	0	y		x	x	x	y	Upper Partlow	Pen	554	534	S	Por	x	AM		
27	0	486		x	x	x	32.2	See below							AM	Mis	1,160
28	0	y		x	x	x	y	Claypool sand	Pen	549	392	S	Por	x	AM		
29	0	y		x	x	x	y	Casey sand	Pen	518	453	S	Por	x	AM		
30	0	y		x	x	x	y	Upper Partlow	Pen	570	489	S	Por	x	AM		
31	0	y		x	x	x	28.5	Lower Partlow	Pen	618	598	S	Por	x	AM		
32	0	403		x	x	x	33.7	See below							AM	MisL	1,471
33	0	y		x	x	x	(32.4)	"500 Ft." sand	Pen	726	561	S	Por	x	AM		
34	0	y		x	x	x	y	"800 Ft." sand	Pen	907	817	S	Por	x	AM		
35	0	y		x	x	x	(37.0)	"900 Ft." sand	MisU	920	886	S	Por	x	AM		
36	0	3,234	26	x	x	x	33.0							33±			
37	0	5,193	27	425±	y	y	33.0	See below[32]								Trenton (Ord)	4,620
38	0	y		x	x	x	y	Shallow sand	Pen	822	508	S	Por	x	ML		
39	0	y	28	x	x	x	32.8	Robinson sand	Pen	960	900	S	Por	25±	ML	Trenton (Ord)	4,620
40	0	y		x	x	x	y	Oblong	Mis	1,416	1,337	S or L	Por	x	A, ML	Mis	1,479

22 Pressures in the southeastern Illinois oil fields are estimated bottom-hole pressures reported in previous Survey publications.

23 All gravities given prior to 1936 (except those in parentheses) were from data for the year 1925 furnished by the Illinois Pipe Line Co. Gravities in parentheses are for particular samples; see Illinois State Geol. Survey *Bull.* 54, Table 3. The values have been converted from Baumé to A.P.I. gravities.

24 Air, 7.

25 Gas, 1; air, 15.

26 Gas, 1; air-gas, 5; air, 24.

27 Gas, 16; air-gas, 20; air, 54.

28 Gas, 16; air-gas, 20; air, 54; water, 1.

32 The Salvage Oil and Gas Co.—W. S. McGrillis No. 3, sec. 25, T. 8 N., R. 13 W., is producing in the "McClosky sand" at a depth of from 1409 to 1415 ft.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells				
			Oil	Gas[a]	To End of 1938	During 1938	To End of 1938	During 1938	Completed to End of 1938	During 1938 Completed	During 1938 Abandoned	At End of 1938 Producing Oil[b]	At End of 1938 Producing Gas[c]
41	New Hebron, *Crawford*	29	1,350	210	*x*	*x*	*x*	*x*	296	0	2	178	0
42	Chapman, *Crawford*	24	1,045	515	*x*	*x*	*x*	*x*	193	0	3	72	0
43	Parker, *Crawford*	31	1,310	30	*x*	*x*	*x*	*x*	256	0	1	216	0
44	Allison-Weger, *Crawford*	*y*	1,075	20	*x*	*x*	*x*	*x*	146	0	0	65	0
45	Flat Rock,[3] *Crawford*	*y*	1,375	545	*x*	*x*	*x*	*x*	289	3	7	149	0
46	Birds, *Crawford, Lawrence*	*y*	4,370	115	*x*	*x*	*x*	*x*	684	0	1	474	0
47	Crawford County Division[4]		45,655	1,945	143,619,000	1,597,000	*x*	*y*	9,193	6	52	6,347	0
48	Lawrence, *Lawrence, Crawford*	32	24,150	1,550	*x*	*x*	*x*	*x*	4,399	11	27	3,200	0
49			5,015	35	*x*	*x*	*x*	*x*	1,231	0	*y*	*y*	0
50			2,240	0	*x*	*x*	*x*	*x*	475	0	*y*	*y*	0
51			345	1,095	*x*	*x*	*x*	*x*	243	0	*y*	*y*	0
52			15,960	220	*x*	*x*	*x*	*x*	3,017	0	*y*	*y*	0
53			4,020	200	*x*	*x*	*x*	*x*	684	0	*y*	*y*	0
54			6,950	0	*x*	*x*	*x*	*x*	957	0	*y*	*y*	0
55	St. Francisville, *Lawrence*	*y*	420	0	*x*	*x*	*x*	*x*	54	0	*y*	45	0
56	Lawrence County Division[5]		24,570	1,550	223,132,000	1,751,000	*x*	*y*	9,185	11	27	3,245	0
57	Allendale, *Wabash*	26	1,680	0	4,656,000	384,000	*x*	*y*	427	7	3	326	0
58	Total Southeastern Illinois field[6]		91,855	3,970	423,541,030	3,925,630	*x*	*y*	19,064	29	126	13,152	0
59	Colmar-Plymouth, *Hancock, McDonough*	25	2,450	0	2,415,970	128,170	0	0	477	2	0	209	0
60	Pike County Gas, *Pike*	33[7]	0	8,960	0	0	*x*	0	68	0	0	0	0
61	Jacksonville Gas, *Morgan*	28[8]	30	1,290	2,100	0	*x*	0	53	0	*y*	0	0
62	Carlinville, *Macoupin*	29[9]	30	50	*x*	0	*x*	0	8	0	0	0	0
63	Spanish Needle Creek, *Macoupin*	23[10]	0	80	0	0	14.4	0	7	0	*y*	0	0
64	Gillespie-Wyen, *Macoupin*	23	40	0	*x*	0	0	0	22	0	0	0	0
65	Gillespie-Benld Gas, *Macoupin*	15[11]	0	80	0	0	135.8	0	4	0	0	0	0
66	Staunton Gas, *Macoupin*	22[12]	0	400	0	0	1,050	0	18	0	0	0	0
67	Litchfield, *Montgomery*	59[13]	100	0	22,000	0	*x*	0	17	0	0	0	0
68	Collinsville, *Madison*	29[14]	40	0	715	0	0	0	5	0	0	0	0
69	Ayers Gas, *Bond*	16	0	325	0	0	167	23.2	19	1	0	0	10
70	Greenville Gas, *Bond*	28[15]	0	160	0	0	990	0	4	0	0	0	0
71	Carlyle, *Clinton*	27	915	0	3,344,400	27,200	0	0	165	0	0	78	0
72	Frogtown, *Clinton*	20[16]	300	0	*x*	0	0	0	12	0	0	0	0
73	Sandoval, *Marion*	29	770	0	2,645,800	15,000	0	0	123	0	0	37	0
74	Centralia, *Marion*	28	175	0	*x*	*y*	0	0	22	0	0	3	0

[3] Includes Swearingen gas.
[4] Total of lines 37, 41, 42, 43, 44, 45, 46.
[5] Total of lines 48 and 55.
[6] Total of lines 36, 47, 56, 57.
[7] Abandoned 1930.
[8] Abandoned 1937.
[9] Abandoned 1925±.
[10] Abandoned 1934.
[11] Abandoned 1935.
[12] Abandoned 1919.
[13] Abandoned 1904.
[14] Abandoned 1921.
[15] Abandoned 1923.
[16] Abandoned 1933.

Natural Gas

Natural gas was produced commercially in two fields in Illinois during 1938, the Ayers field, Bond County (productive since 1922), and the Russellville field, Lawrence County.

Table 1.—(*Continued*)

Line Number	Oil-production Methods at End of 1938: Number of Wells: Flowing	Pumping	Air, Gas, Water Lift	Pressure, Lb. per Sq. In.[d22]: Initial	Average at End of 1937	1938	Character of Oil, Approx. Average during 1938: Gravity A.P.I. at 60° F.[23] Weighted Average	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
41	0	178		x	x	x	30.1	Robinson sand[33]	Pen	975	940	S	Por	x	ML	MisL	2,056
42	0	72		x	x	x	y	Robinson sand	Pen	1,015	995	S	Por	x	ML	Mis	2,279
43	0	216		x	x	x	y	Robinson sand	Pen	1,025	1,000	S	Por	x	ML	Pen?	1,127
44	0	65		x	x	x	29.5	Robinson sand	Pen	930	912	S	Por	x	ML	Pen	1,041
45	0	149		x	x	x	22.5	Robinson (Flat Rock)	Pen	945	935	S	Por	x	ML	Pen	1,032
46	0	474		x	x	x	31.8	Robinson sand	Pen	950	930	S	Por	x	ML	MisL	1,731
47	0	6,347	[29]	425±	x	x	32.3		Pen, Mis			S	Por		ML	Trenton (Ord)	4,620
48	0	3,200		650±	x	x	32.9	See below							A	St. Peter	5,190
49	0	y		x	x	x	y	Bridgeport sand	Pen	1,000	800	S	Por	40	A		
50	0	y		x	x	x	y	Buchanan	Pen	1,265	1,250	S	Por	15	A		
51	0	y		x	x	x	y	"Gas" sand	MisU	1,345	1,330	S	Por	15	A		
52	0	y		600±	x	x	y	Kirkwood	MisU	1,430	1,400	S	Por	30	A		
53	0	y		650	x	x	y	Tracey	MisU	1,580	1,560	S	Por	20	A		
54	0	y		x	x	x	y	McClosky	MisL	1,710	1,700	L	Por	10	A		
55	0	45		600	x	x	37.3	Kirkwood	MisU	1,865	1,843	S	Por	22	ML	Mis	1,900
56	0	3,245			x	x										St. Peter	5,190
57	0	326		x	x	x	35.1	Biehl sand	Pen	1,460	1,425	S	Por	20	AM		
58	0	13,152	[30]				33.1										
59	0	209		x	x	x	y	Hoing sand	Dev	468	447	S	Por	21	A	Trenton (Ord)	805
60	0	0		x	x	x		"Niagaran"	Sil	275	265	L	Por	10	A	St. Peter	893
61	0	0		x	x	x	x	Gas sand	Pen, Mis	335	330	S, SL	Por	5	ML	Trenton (Ord)	1,390
62	0	0		135	x	x	27.7	Unnamed	Pen	398	380	S	Por	x	A	Pen	410
63	0	0		y	y	y		Unnamed	Pen	405	305	S	Por	x	D	Pen	495
64	0	0		x	x	x	30.0	Unnamed	Pen	670	650	S	Por	x	T	Trenton (Ord)	2,560
65	0	0		155	x	x		Unnamed	Pen	555	542	S	Por	x	A	Pen	575
66	0	0		145	x	x		Unnamed	Pen	491	461	S	Por	x	A	Trenton (Ord)	2,371
67	0	0		x	x	x	21.7	Unnamed	Pen	674	664	S	Por	x	D	Pen	681
68	0	0		x	x	x	x	Devonian-Silurian	Dev-Sil	1,400	1,305	L	Por	20	ML	Silurian	1,500
69	0	0		335	310	310		Lindley (2d)	MisU	945	940	S	Por	5	A	MisL	1,150
70	0	0		x	x	x		Lindley (1st, 2d)	MisU	993	927	S	Por	x	A	Mis	1,065
71	0	78		x	x	x	35.2	Carlyle	MisU	1,055	1,035	S	Por	20	A	Sil	2,620
72	0	0		x	x	x	31.9	Carlyle	MisU	957	950	S	Por	7	0	Carlyle y	962±
73	0	37		x	x	x	34.5	Benoist	MisU	1,560	1,540	S	Por	20±	D	Mis	1,732
74	0	3		x	x	x	32.0	Dykstra, Wilson, Benoist	Pen, MisU	1,150	1,130	S	Por	20	D ML	MisL	1,779

[29] Gas, 17; air-gas, 24; air, 53; water, 1.
[30] Gas, 18; air-gas, 29; air, 79; water, 7.
[33] The West Union Oil and Gas Co.—Ducommon No. 1, sec. 28, T. 6 N., R. 12 W., is producing in the "McClosky sand," from 1506 to 1528 ft.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres: Oil	Area Proved, Acres: Gas[a]	Total Oil Production, Bbl.: To End of 1938	Total Oil Production, Bbl.: During 1938	Total Gas Production, Millions Cu. Ft.: To End of 1938	Total Gas Production, Millions Cu. Ft.: During 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Producing Oil[b]	At End of 1938: Producing Gas[c]
75	Wamac, *Clinton, Marion, Washington*	17	250	0	382,530	9,780	0	0	104	1	0	46	0
76	Dupo, *St. Clair*	10	670	0	946,870	36,100	0	0	242	5	0	30	0
77	Waterloo, *Monroe*	18[17]	125	0	166,000	0	0	0	23	0	0	0	0
78	Sparta Gas, *Randolph*	21[18]	65	100	*x*	0	*x*	0	20	0	0	0	0
79	Ava-Campbell Hill, *Jackson*	21[19]	70	370	25,000	0	*x*	0	35	0	0	0	0
80	Bartelso, *Clinton*	3	165	0	253,570	161,870	0	0	38	17	0	37	0
81	Decatur, *Macon*	2[20]	10	0	1,000	400	0	0	2	0	0	0	0
82	Total for fields prior to 1-1-37[21]		98,060	15,785	433,746,980	4,304,150	2,357.2	23.2	20,550	55	126	13,592	10
83	Sorento, *Bond*	1	10	0	*y*	*y*	0	0	1	1	0	0	0
84	Beecher City-Louden, *Fayette*	2	15,860	0	1,892,000	1,892,000	0	0	488	486	0	488	0
85			*y*	0	*y*	*y*	0	0	250	248	0	250	0
86			*y*	0	*y*	*y*	0	0	18	18	0	18	0
87			*y*	0	*y*	*y*	0	0	220	220	0	220	0
88	St. James, *Fayette*	1	270	0	48,000	48,000	0	0	24	24	0	24	0
89	Patoka, *Marion*	2	465	0	1,167,000	742,000	0	0	115	22	11	104	0
90	Lake Centralia-Salem, *Marion*	1	7,520	0	2,895,000	2,895,000	0	0	480	480	0	476	0
91			*y*	0	*y*	*y*	0	0	442	442	0	*y*	0
92			*y*	0	*y*	*y*	0	0	21	21	0	*y*	0
93			*y*	0	*y*	*y*	0	0	17	17	0	*y*	0
94	Centralia (New), *Clinton, Marion*	2	2,000	0	3,027,000	3,022,000	0	0	526	524	0	526	0
95			*y*	0	*y*	*y*	0	0	12	12	0	12	0
96			*y*	0	*y*	*y*	0	0	514	512	0	512	0
97	Dix, *Jefferson*	1	615	0	*y*	*y*	0	0	35	35	0	35	0
98	Roaches, *Jefferson*	1	20	0	*y*	*y*	0	0	2	2	0	2	0
99	Marcoe, *Jefferson*	1	10	0	*y*	*y*	0	0	1	1	0	1	0
100	Elk Prairie, *Jefferson*	1	10	0	*y*	*y*	0	0	1	1	0	1	0
101	Ina, *Jefferson*	1	10	0	*y*	*y*	0	0	1	1	0	1	0
102	Flora, *Clay*	1	140	0	68,000	68,000	0	0	9	9	0	9	0
103	Clay City, *Clay, Wayne*	2	4,750	0	5,560,000	4,004,000	0	0	222	144	0	222	0
104	Noble, *Richland*	2	3,150	0	5,179,000	4,232,000	0	0	153	108	8	141	0
105			*y*	0	*y*	*y*	0	0	6	6	0	6	0
106			3,150	0	*y*	*y*	0	0	145	102	8	135	
107	Schnell, *Richland*	1	40	0	*y*	*y*	0	0	4	4	0	4	0
108	Olney, *Richland*	2	380	0	415,000	414,000	0	0	30	29	0	28	0
109	Rinard, *Wayne*	2	10	0	*y*	*y*	0	0	1	0	0	1	0
110	Cisne, *Wayne*	2	575	0	*y*	*y*	0	0	26	23	0	25	0
111			20	0	*y*	*y*	0	0	2	0	0	2	0
112			555	0	*y*	*y*	0	0	24	22	0	23	0
113	Boyleston, *Wayne*	1	10	0	*y*	*y*	0	0	1	1	0	1	0
114	Aden, *Wayne*	1	160	0	*y*	*y*	0	0	4	4	0	4	0
115	North Aden, *Wayne*	1	690	0	305,000	305,000	0	0	40	40	0	40	0
116	Mt. Erie, *Wayne*	1	10	0	*y*	*y*	0	0	1	1	0	1	0
117	Leech Twp., *Wayne*	1	20	0	*y*	*y*	0	0	2	2	0	2	0
118	Russellville Gas, *Lawrence*	2	0	500	0	0	101.4	99.1	15	13	0	0	15
119	North		0	20	0	0	6.8	4.5	2	0	0	0	2
120	South		0	480	0	0	94.6	94.6	13	13	0	0	13
121	Total for fields after Jan. Jan. 1, 1937[36]		36,725	500	22,549,000	19,665,000	101.4	99.1	2,182	1,955	19	2,136	15
122	Total for Illinois[37]		134,785	16,285	456,850,000[34]	23,929,000[34]	2,458.6	122.3	22,732	2,010	145	15,728	25

[17] Abandoned 1930.
[18] Abandoned 1900.
[19] Abandoned 1934.
[20] Wells drilled in 1922 and 1924, first production in 1937.
[21] Total of lines 58 to 81 inclusive.
[34] Gas, 5.
[36] Total of lines 83 to 120 inclusive.
[37] Total of lines 82 and 121.

TABLE 1.—(*Continued*)

Line Number	Oil-production Methods at End of 1938: Number of Wells: Flowing	Pumping	Air, Gas, Water Lift	Pressure, Lb. per Sq. In.: Initial	Average at End of: 1937	1938	Character of Oil, Approx. Average during 1938: Gravity A.P.I. at 60° F.[23]: Weighted Average	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
75	0	46		*x*	*x*	*x*	30.2	Petro	Pen	760	720	S	Por	20	D	MisL	1,760
76	0	30		*x*	*x*	*x*	32.7	Trenton	Ord	651	601	L	Por, Cav	50	A	Trenton (Ord)	819
77	0	0		*x*	*x*	*x*	30.0	Trenton	Ord	460	410	L	Por	50	A	Trenton (Ord)	845
78	0	0		*x*	*x*	*x*	*x*	Sparta gas sand	MisU	857	850	S	Por	7	D	MisU	985
79	0	0		*x*	*x*	*x*	*x*	Unnamed	MisU	798	780	S	Por	18	A	Dev	2,530
80	0	37		*x*	*x*	*x*	32.0	Carlyle	MisU	1,008	984	S	Por	24	D	MisU	1,118
81	0	2		*x*	*x*	*x*	39.5	"Niagaran"	Dev	2,076	2,020	L	Por	30	N	St. Peter	2,991
82	0	13,592	[31]		0												
83	0	0		*y*	0	*y*	*y*	Devonian	Dev	1,830	1,800	L	Por	*y*	D	Devonian	1,830
84	135	353	[34]	*y*	*y*	*y*	37	See below							A	Devonian	3,170
85	*y*	*y*		*y*	*y*	e500	*y*	Cypress	MisU	1,541	1,510	S	Por	29			
86	*y*	*y*		*y*	0	*y*	*y*	Stray	MisU	1,561	1,542	S	Por	15			
87	*y*	*y*		*y*	0	e575	*y*	Bethel	MisU	1,566	1,542	S	Por	21			
88	0	24		*y*	*y*	*y*	37	Cypress	MisU	1,624	1,603	S	Por	19	A	MisU	1,636
89	0	104		*x*	*x*	*x*	39.5	Bethel	MisU	1,440	1,424	S	Por	16	A	MisL	1,675
90	127	349		*y*	*y*	*y*	39.5								A	MisL	2,192
91	*y*	*y*		*y*	*y*	*y*	*y*	Bethel	MisU	1,817	1,776	S	Por	38			
92	*y*	*y*		*y*	*y*	*y*	*y*	Aux Vases	MisU	1,850	1,801	S	Por	34			
93	*y*	*y*		*y*	*y*	*y*	*y*	McClosky	MisL	2,035	2,000	L	Por	19			
94	0	526		*y*	*y*	{ 10 e250	36.1								A	MisL	1,646
95	0	12		*y*	*y*	*y*	*y*	Cypress	MisU	1,225	1,200	S	Por	19			
96	0	514		*y*	*y*	*y*	*y*	Bethel	MisU	1,378	1,355	S	Por	23			
97	0	35		*y*	*y*	e730	38	Bethel	MisU	1,965	1,950	S	Por	15	A	Devonian	3,874
98	0	2		*y*	*y*	*y*	*y*	Ste. Genevieve	MisL	2,271	2,192	S, L	Por	12	D?	MisL	2,263
99	0	1		*y*	*y*	*y*	*y*	McClosky	MisL	2,765	2,746	L	Por	11	D?	MisL	2,800
100	0	1		*y*	*y*	*y*	*y*	McClosky	MisL	2,751	2,718	L	Por	7	D?	MisL	2,958
101	0	1		*y*	*y*	*y*	*y*	St. Louis	MisL	3,007	3,002	L	Por	5	D	MisL	3,007
102	0	9		*y*	*y*	*y*	38.5	McClosky	MisL	2,982	2,966	L	Por	7	*y*	MisL	3,100
103	28	194		*y*	*y*	*y*	38.5	McClosky	MisL	3,035	2,984	L	Por	9	A	MisL	3,197
104	0	141		*y*	*y*	*y*	38.5								A	MisL	3,115
105	0	6		*y*	*y*	*y*	38.5	Cypress	MisU	2,602	2,569	S	Por	20			
106	0	135		*y*	*y*	*y*	38.5	McClosky	MisL	3,003	2,957	L	Por	10			
107	0	4		*y*	*y*	*y*	38.5	McClosky	MisL	3,068	3,012	L	Por	6	D	MisL	3,130
108	2	26		*y*	*y*	350	39.1	McClosky	MisL	3,073	3,052	L	Por	9	A	MisL	3,137
109	0	1		*y*	*y*	*y*	38.5	McClosky	MisL	3,154	3,144	L	Por	5	D	MisL	3,154
110	17	8		*y*	*y*	*y*	38.5								A	MisL	3,273
111	0	2		*y*	*y*	*y*	38.5	Aux Vases	MisU	3,026	2,982	S	Por	13			
112	17	6		*y*	*y*	*y*	38.5	McClosky	MisL	3,137	3,117	L	Por	10			
113	0	1		*y*	*y*	*y*	38.5	McClosky	MisL	3,269	3,253	L	Por	12	A?	MisL	3,269
114	0	4		*y*	*y*	*y*	38.5	McClosky	MisL	3,337	3,287	L	Por	7	A	MisL	3,460
115	34	6		*y*	*y*	400	38.5	McClosky	MisL	3,335	3,315	L	Por	13	A	MisL	3,440
116	0	1		*y*	*y*	*y*	38.5	McClosky	MisL	3,092	3,080	L	Por	*y*	D?	MisL	3,135
117	0	2		*y*	*y*	*y*	38.5	McClosky	MisL	3,461	3,446	L	Por	7	D?	MisL	3,438
118				*y*	*y*	380									A		
119				*y*	*y*	*y*		Pen sand	Pen	622	619	S	Por	12		MisL	2,012
120				*y*	*y*	*y*		Buchanan	Pen	1,100	1,090	S	Por	10		Pen	1,158
121	343	1,793	[34]														
122	343	15,385	[35]														

[31] Gas, 18; air-gas, 29; air, 171; water, 28.
[35] Gas, 23; air-gas, 29; air, 171. water, 28.

TABLE 2.—*Summary of Drilling Operations in Illinois*

Important Wildcats Drilled in 1938*

	County	Location			Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks	Field Name of New Discoveries and Extensions
		Sec. Survey	Twp. Lat.	Rge. Long.				Oil, U.S. Bbl.	Gas, Millions Cu. Ft.		
1	Bond........	30	4 N	2 W	1,385	Ste. Genevieve	W. C. McBride, Inc.			Dry	
2	Bond........	30	6 N	3 W	1,030	Ste. Genevieve	O. M. Nethery			Dry	
3	Bond........	26	6 N	2 W	3,350	"Trenton"	A. T. Whitehead			Dry	
4	Bond........	24	6 N	4 W	2,045	Devonian	Universal and DeMayo			Dry	
5	Bond........	21	6 N	4 W	1,870	"Niagaran"	File et al.			Dry	
6	Bond........	24	4 N	2 W	1,380	Bethel	Leavitt & Holland			Dry	
7	Bond........	31	4 N	2 W	1,323	Ste. Genevieve	Lindsay Bros.			Dry	
8	Bond........	28	4 N	4 W	1,337	St. Louis	John Farrelly			Dry	
9	Bond........	33	4 N	4 W	1,130	St. Louis	Lindsey Bros. & Brit. Am.			Dry	
10	Bond........	21	6 N	4 W	1,835	"Niagaran"	DeMayo et al.	15			Sorento
11	Brown........	4	1 S	2 W	573	Mississippian	Fell Oil Trust			Dry	
12	Brown........	15	1 S	2 W	642	"Niagaran"	Fell Oil Trust			Dry	
13	Bureau......	8	17 N	6 E	1,347	St. Peter	Harrington Bros.			Dry	
14	Bureau......	24	15 N	9 E	450	Pennsylvanian	John R. Lewis et al.			Dry	
15	Cass.........	30	17 N	12 W	585	"Niagaran"	Ed Duval			Dry	
16	Champaign...	9	17 N	10 E	350	Pennsylvanian	Casey-Edwards Oil Co.		1.5[1]		
17	Champaign...	33	18 N	10 E	480	L. Mississippian	Nedra Oil & Gas Co.			Dry	
18	Champaign...	20	20 N	8 E	610	Devonian	Barber & Siever			Dry	
19	Christian....	23	11 N	1 E	1,727	Ste. Genevieve	Independent Prod. & Ref.			Dry	
20	Christian....	23	11 N	1 E	1,801	St. Louis	Swords & McDougal			Dry	
21	Christian....	32	12 N	1 W	1,457	Ste. Genevieve	Brown & Lacy			Dry	
22	Christian....	29	12 N	2 W	1,010	L. Chester	Nokomis Oil Co.			Dry	
23	Clark........	17	10 N	11 W	2,555	Devonian	Pierson & Yeager			Dry	
24	Clark........	21	11 N	12 W	2,451	"Niagaran"	Nat'l Consumers Oil Co.			Dry	
25	Clark........	30	12 N	13 W	403	Pennsylvanian	Stipes et al.		0.250[1]		
26	Clark........	19	12 N	14 W	410	B. Pennsylvanian	W. R. Miller et al.			Dry	
27	Clark........	29	12 N	13 W	525	L. Pennsylvanian	J. W. Stipes et al.			Dry	
28	Clark........	17	11 N	12 W	2,440	"Niagaran"	Mid-American Resource Co.			Dry	
29	Clay.........	19	3 N	8 E	3,047	"McClosky"	Danville Oil Drillers, Inc.	124			Clay City extension
30	Clay.........	12	2 N	7 E	3,076	Ste. Genevieve	Wiser Oil Co.	273			Clay City extension
31	Clay.........	23	3 N	7 E	3,147	Ste. Genevieve	J. L. Tallman et al.			Dry	
32	Clay.........	19	3 N	8 E	3,098	Ste. Genevieve	Nu Crude Oil Co.			Dry	
33	Clay.........	13	3 N	6 E	2,983	Ste. Genevieve	Kingwood Oil Co.	550			Flora
34	Clay.........	24	4 N	8 E	3,150	Ste. Genevieve	Ohio Oil Co.			Dry	
35	Clay.........	14	4 N	5 E	4,325	"Niagaran"	Carter Oil Co.			Dry	
36	Clay.........	35	3 N	8 E	3,074	Ste. Genevieve	Eureka Oil Co.			Dry	
37	Clay.........	9	3 N	7 E	2,967	Ste. Genevieve	Ohio Oil Co.	459			Flora extension
38	Clay.........	32	3 N	5 E	3,030	Ste. Genevieve	Gordin & Robinson			Dry	
39	Clinton......	18	3 N	2 W	1,188	Bethel	Hawley & Willis			Dry	
40	Clinton......	4	3 N	2 W	1,406	L. Mississippian	Phelps et al.			Dry	
41	Clinton......	13	1 N	1 W	1,370	Bethel	Adams Oil & Gas Co.	275			Centralia (New) extension
42	Clinton......	13	1 N	1 W	1,444	Bethel	Paul Henshaw			Dry	
43	Clinton......	22	1 N	4 W	1,030	L. Chester	Gross, Erling & Murphy			Dry	
44	Clinton......	18	3 N	2 W	1,454	Ste. Genevieve	Hawley & Willis			Dry	
45	Clinton......	21	1 N	1 W	1,420	Bethel	Brookside Oil Co.			Dry	
46	Clinton......	4	2 N	1 W	1,733	Ste. Genevieve	Sigel & Schlosberg			Dry	
47	Clinton......	28	2 N	1 W	1,750	L. Mississippian	Penn.-Ill. Oil Co.			Dry	
48	Clinton......	3	2 N	5 W	1,352	Salem	Kennedy & Plangle			Dry	
49	Clinton......	16	1 N	2 W	1,509	Ste. Genevieve	F. L. Heldt			Dry	

* One mile or more from production.

[1] Gas well for local use.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	County	Location Sec. Survey	Location Twp. Lat.	Location Rge. Long.	Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day Oil, U.S. Bbl.	Initial Production per Day Gas, Millions Cu. Ft.	Remarks	Field Name of New Discoveries and Extensions
50	Clinton......	35	2 N	2 W	1,370	Bethel	R. A. Wilson et al.			Dry	
51	Clinton......	14	2 N	1 W	1,795	Ste. Genevieve	Trahan et al.			Dry	
52	Clinton......	23	2 N	2 W	1,560	Ste. Genevieve	Hausman et al.			Dry	
53	Clinton......	5	3 N	1 W	1,620	Ste. Genevieve	Taylor Drilling Co.			Dry	
54	Clinton......	10	3 N	2 W	1,276	Bethel	M & K Oil Co.			Dry	
55	Clinton......	30	1 N	4 W	1,403	L. Mississippian	Farrelly et al.			Dry	
56	Clinton......	35	1 N	5 W	1,290	St. Louis	Martin et al.			Dry	
57	Clinton......	19	3 N	2 W	1,183	Bethel	White et al.			Dry	
58	Clinton......	22	3 N	2 W	1,150	Bethel	Sappington et al.			Dry	
59	Clinton......	7	1 N	2 W	1,498	St. Louis	Phillips Petroleum Co.			Dry	
60	Clinton......	24	1 N	3 W	1,360	Bethel	Watkins & Wright			Dry	
61	Clinton......	21	2 N	3 W	1,355	Ste. Genevieve	A. C. Thomas et al.			Dry	
62	Clinton......	35	2 N	3 W	1,370	Ste. Genevieve	Pass et al.			Dry	
63	Clinton......	10	3 N	1 W	1,529	Bethel	G. N. Moore			Dry	
64	Clinton......	28	3 N	2 W	1,389	Ste. Genevieve	Lou Huddleston et al.			Dry	
65	Coles........	31	14 N	14 W	1,203	Silurian	Gregory & Mechling			Dry	
66	Coles........	27	13 N	9 E	903	L. Mississippian	W. E. Hughes			Dry	
67	Coles........	21	11 N	10 E	3,532	"Trenton"	Kingwood Oil Co.			Dry	
68	Coles........	21	11 N	7 E	2,286	Ste. Genevieve	B. Wafford et al.			Dry	
69	Coles........	9	12 N	7 E	2,277	St. Louis	Thompson Drilling Co.			Dry	
70	Coles........	30	14 N	14 W	1,134	"Niagaran"	Mabee et al.			Dry	
71	Coles........	27	13 N	8 E	2,105	Bethel	Ed Swearer & Crown Petr. Co.			Dry	
72	Coles........	36	14 N	10 E	1,300	Devonian-Silurian	East Oakland Syndicate			Dry	
73	Crawford....	34	8 N	12 W	1,030	Basal Pennsylvanian	Darnell et al.			Dry	
74	Crawford....	18	5 N	10 W	955	Basal Pennsylvanian	Kentucky Natural Gas Co.			Dry	
75	Crawford....	24	6 N	12 W	1,027	Basal Pennsylvanian	Dill-Thalman et al.			Dry	
76	Crawford....	19	5 N	10 W	1,450	Ste. Genevieve	Kentucky Natural Gas Corp.			Dry	
77	Crawford....	6	6 N	11 W	1,621	Ste. Genevieve	Mahutska Oil Co.			Dry	
78	Crawford....	18	8 N	12 W	2,952	Devonian	Warren Hastings			Dry	
79	Cumberland..	30	10 N	9 E	2,330	L. Chester	Stipes et al.			Dry	
80	Cumberland..	26	9 N	9 E	2,825	Fredonia	Stewart Oil Co.			Dry	
81	Cumberland..	27	11 N	8 E	2,411	St. Louis	Phillips Petroleum Co.			Dry	
82	Cumberland..	18	10 N	7 E	2,301	Ste. Genevieve	Hanshaw Bros.			Dry	
83	Cumberland..	29	10 N	9 E	2,680	Ste. Genevieve	Jefferies & Cobb			Dry	
84	Edgar.......	22	13 N	12 W	2,314	"Niagaran"	Sun Oil Co.			Dry	
85	Edgar.......	18	12 N	13 W	1,000	L. Mississippian	J. W. Stipes et al.			Dry	
86	Edgar.......	15	14 N	11 W	2,160	"Niagaran"	J. M. Huber Corp.			Dry	
87	Edgar.......	16	14 N	13 W	670	L. Mississippian	Elmer Lapsley			Dry	
88	Edgar.......	24	14 N	14 W	544	L. Mississippian	Pearcy			Dry	
89	Effingham....	32	8 N	6 E	2,709	L. Mississippian	Hollis et al.			Dry	
90	Effingham....	18	6 N	7 E	2,900	St. Louis	Graham & Duncan			Dry	
91	Effingham....	15	6 N	6 E	5,823	Middle Ordovician	Kingwood Oil Co.			Dry	
92	Effingham....	24	8 N	4 E	2,700	L. Mississippian	Penn.-Ill. Oil & Gas Co.			Dry	
93	Effingham....	22	7 N	4 E	2,404	Ste. Genevieve	Kingwood & Baker			Dry	
94	Effingham....	20	9 N	4 E	2,012	Ste. Genevieve	Carter Oil Co.			Dry	
95	Effingham....	27	8 N	4 E	2,036	Basal Chester	W. D. Anderson			Dry	
96	Effingham....	31	9 N	4 E	1,656	Bethel	Carter Oil Co.			Dry	
97	Fayette......	24	9 N	1 E	1,850	Ste. Genevieve	Ryan & Redgraves			Dry	

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	County	Location			Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks	Field Name of New Discoveries and Extensions
		Sec. Survey	Twp. Lat.	Rge. Long.				Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		
98	Fayette......	16	8 N	3 E	1,573	Bethel	Farrelly et al.	35			Beecher City—Louden extension
99	Fayette......	36	9 N	3 E	1,672	Bethel	Whisenant & Henshaw			Dry	
100	Fayette......	27	8 N	2 E	1,574	Golconda	Crump, Ritchie & Payne			Dry	
101	Fayette......	34	9 N	3 E	1,662	Bethel	W. F. Lacy			Dry	
102	Fayette......	24	7 N	2 E	1,942	Ste. Genevieve	Sharp & Divers			Dry	
103	Fayette......	2	7 N	2 E	1,665	L. Chester	Sol Simon et al.			Dry	
104	Fayette......	24	8 N	2 E	1,500	L. Chester	Trares et al.			Dry	
105	Fayette......	34	5 N	1 W	1,546	Bethel	Wheless & Whisenant			Dry	
106	Fayette......	19	8 N	3 E	1,757	Bethel	W. C. McBride, Inc.			Dry	
107	Fayette......	14	4 N	1 W	1,462	Bethel	Wheeler & Whisenant			Dry	
108	Fayette......	16	5 N	2 E	1,919	Bethel	Finley & Greer			Dry	
109	Fayette......	10	6 N	3 E	1,912	Bethel	Joe Sharp & J. Divers			Dry	
110	Fayette......	1	7 N	2 E	1,760	Bethel	Pat Hudson			Dry	
111	Fayette......	6	8 N	3 E	1,772	Bethel	Iroquois Oil & Gas Co.			Dry	
112	Fayette......	20	6 N	3 E	1,810	Bethel	Whisenant et al.			Dry	
113	Fayette......	30	6 N	3 E	1,622	Cypress	Rosenthal	188			St. James
114	Fayette......	12	7 N	2 E	1,800	Bethel	Ruwaldt & Johnson			Dry	
115	Fayette......	3	8 N	1 E	1,822	St. Louis	Phillips Petroleum Corp.			Dry	
116	Fayette......	4	8 N	3 E	1,690	Cypress	Bell Oil & Gas Co.			Dry	
117	Fayette......	35	8 N	3 E	1,637	Bethel	DeKalb Syndicate			Dry	
118	Fayette......	8	5 N	1 E	1,602	Bethel	Burroughs			Dry	
119	Fayette......	1	5 N	2 E	1,802	Bethel	Longovia et al.			Dry	
120	Fayette......	25	6 N	2 E	1,820	Bethel	W. B. Johnson			Dry	
121	Fayette......	5	6 N	3 E	1,753	Aux Vases	Jarvis Bros.			Dry	
122	Fayette......	12	6 N	3 E	2,201	"McClosky"	J. C. Cole et al.			Dry	
123	Fayette......	19	6 N	3 E	1,980	"McClosky"	F. H. Brown et al.			Dry	
124	Fayette......	16	7 N	3 E	1,593	Bethel	Cummings et al.			Dry	
125	Fayette......	34	9 N	2 E	1,850	Basal Chester	Bob Garland			Dry	
126	Fayette......	2	6 N	2 E	1,952	Bethel	Zephyr Drilling Co.			Dry	
127	Fayette......	35	6 N	1 W	1,434	Bethel	Putman et al.			Dry	
128	Fayette......	32	6 N	3 E	1,852	Bethel	Mammoth Prod. & Ref.			Dry	
129	Fayette......	30	5 N	1 E	1,580	Bethel	W. C. Stephenson et al.			Dry	
130	Fayette......	30	7 N	3 E	1,647	Bethel	Whisenant et al.			Dry	
131	Fayette......	33	7 N	3 E	1,910	Ste. Genevieve	Jarvis Bros.			Dry	
132	Fayette......	29	8 N	1 E	1,695	Ste. Genevieve	Producers Oil Co.			Dry	
133	Fayette......	33	8 N	1 E	1,640	Basal Chester	Doran & Haynes			Dry	
134	Fayette......	30	9 N	1 E	1,775	Ste. Genevieve	Continental Oil Co.			Dry	
135	Fayette......	36	4 N	1 W	1,702	Ste. Genevieve	Lindsey et al.			Dry	
136	Fayette......	16	5 N	1 E	1,656	Bethel	American Seismograph Co.			Dry	
137	Fayette......	8	6 N	3 E	2,001	Ste. Genevieve	Mylius et al.			Dry	
138	Fayette......	15	6 N	1 W	1,755	L. Mississippian	Hurricane Creek Oil Co.			Dry	
139	Fayette......	35	6 N	1 W	1,434	Bethel	Putman et al.			Dry	
140	Fayette......	18	7 N	2 E	1,970	Ste. Genevieve	Papoose Oil Co.			Dry	
141	Fayette......	31	9 N	3 E	2,200	L. Mississippian	Ullrich & Pough			Dry	
142	Fulton.......	11	7 N	1 E	657	"Niagaran"	Ketcherside & Fisher			Dry	
143	Franklin.....	6	5 S	4 E	3,050	L. Mississippian	Washburn Petroleum Co.			Dry	
144	Franklin.....	18	5 S	3 E	2,946	St. Louis	Markham, Mason & Redwine			Dry	
145	Franklin.....	14	7 S	1 E	3,308	Ste. Genevieve	Amerada Petroleum Co.			Dry	

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	County	Location			Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks	Field Name of New Discoveries and Extensions
		Sec. Survey	Twp. Lat.	Rge. Long.				Oil, U.S. Bbl.	Gas, Millions Cu. Ft.		
146	Franklin	19	5 S	2 E	3,102	St. Louis	Adams Oil & Gas Co.			Dry	
147	Franklin	4	5 S	1 E	3,103	Salem	Buell			Dry	
148	Franklin	36	6 S	2 E	3,197	St. Louis	Eason Oil Co.			Dry	
149	Hamilton	32	3 S	7 E	3,460	Ste. Genevieve	H. H. Weinert, Inc.			Dry	
150	Hancock	1	3 N	5 W	568	Hoing	Callihan et al.			Dry	
151	Hancock	11	4 N	5 W	531	Hoing	Forrest Groves			Dry	
152	Hardin	30	11 S	8 E	2,345	"Trenton"	Maretta Oil Co.			Dry	
153	Iroquois	14	26 N	12 W	1,096	Maquoketa	Whittet et al.			Dry	
154	Jackson	20	7 S	4 W	4,144	St. Peter	Stanolind Oil & Gas Co.			Dry	
155	Jackson	12	7 S	2 W	1,891	"McClosky"	T. T. Eason			Dry	
156	Jackson	11	7 S	2 W	2,007	Ste. Genevieve	W. R. Hayes			Dry	
157	Jasper	33	6 N	14 W	3,018	Ste. Genevieve	Denver Prod. & Ref. Co.			Dry	
158	Jasper	20	8 N	10 E	4,139	Devonian	Hoffman et al.			Dry	
159	Jasper	7	6 N	9 E	2,540	Chester	Richard Eke			Dry	
160	Jasper	3	6 N	9 E	2,708	Lower Chester	Obermayer et al.			Dry	
161	Jasper	33	7 N	9 E	3,210	St. Louis	Continental Oil Co.			Dry	
162	Jasper	30	8 N	10 E	2,694	Ste. Genevieve	Borah et al.			Dry	
163	Jefferson	10	1 S	2 E	2,000	Bethel	Carter Oil Co.	73			Dix[2]
164	Jefferson	23	4 S	3 E	3,150	Ste. Genevieve	Benedum-Trees Oil Co.			Dry	
165	Jefferson	15	1 S	1 E	1,959	Bethel	Dee & Jordan			Dry	
166	Jefferson	6	2 S	2 E	2,467	L. Mississippian	Sturbois & Tomberlin			Dry	
167	Jefferson	16	2 S	1 E	2,380	St. Louis	Dee et al.			Dry	
168	Jefferson	7	1 S	3 E	2,200	Lower Chester	Hausman et al.			Dry	
169	Jefferson	6	1 S	1 E	1,840	Cypress	Crosby & Gill			Dry	
170	Jefferson	6	1 S	1 E	2,132	Ste. Genevieve	J. O. Gill			Dry	
171	Jefferson	4	2 S	2 E	2,552	Ste. Genevieve	Kingwood Oil Co.			Dry	
172	Jefferson	5	1 S	2 E	2,010	Cypress	Case, Hanna et al.			Dry	
173	Jefferson	20	4 S	3 E	2,911	Fredonia	Dee & Foltz			Dry	
174	Jefferson	20	4 S	3 E	2,653	Chester	Dee & Foltz			Dry	
175	Jefferson	25	4 S	2 E	3,003	St. Louis	Nollem Oil & Gas Co.	12			Ina
176	Jefferson	1	1 S	1 E	1,840	Bethel	Sam Jennings et al.			Dry	
177	Jefferson	6	1 S	1 E	1,163	Pennsylvanian	V. O. Lewis			Dry	
178	Jefferson	2	2 S	1 E	2,413	St. Louis	J. G. Buell			Dry	
179	Jefferson	5	3 S	4 E	3,167	"McClosky"	J. G. Buell			Dry	
180	Jefferson	22	2 S	1 E	2,263	"McClosky"	Magnolia Petroleum Co.	217			Roaches
181	Jefferson	16	2 S	1 E	2,958	"McClosky"	Benedum-Trees Oil Co.	20			Elk Prairie
182	Jefferson	28	1 S	2 E	2,238	Ste. Genevieve	Milam et al.			Dry	
183	Jefferson	36	1 S	2 E	2,579	St. Louis	A. S. Walker			Dry	
184	Jefferson	18	1 S	4 E	2,808	Ste. Genevieve	Minerva Oil Co.			Dry	
185	Jefferson	9	2 S	1 E	2,272	Ste. Genevieve	Transwestern Oil Co.			Dry	
186	Jefferson	14	2 S	1 E	2,401	Ste. Genevieve	Luttrell & Holleman			Dry	
187	Jefferson	27	2 S	1 E	2,868	Salem	Magnolia Petroleum Co.			Dry	
188	Jefferson	28	2 S	1 E	2,264	Ste. Genevieve	Dr. Moore et al.			Dry	
189	Jefferson	12	3 S	2 E	2,822	Ste. Genevieve	W. O. Allen et al.			Dry	
190	Jefferson	22	3 S	2 E	2,765	"McClosky"	Magnolia Petroleum Co.	237			Marcoe
191	Jefferson	20	4 S	3 E	3,150	St. Louis	Parker-Price			Dry	
192	Lawrence	20	4 N	11 W	1,215	Bridgeport	Payne et al.			Dry	
193	Lawrence	13	4 N	11 W	1,061	B. Pennsylvanian	Joe Kesl et al.		2.651		South Russellville
194	Lawrence	22	3 N	11 W	2,044	St. Louis	Chester Harris et al.			Dry	
195	Lawrence	14	3 N	11 W	2,000	L. Mississippian	Trio Oil Co.			Dry	
196	Lawrence	23	4 N	11 W	1,750	L. Mississippian	Joe Kesl et al.			Dry	

[2] Well drilled to Devonian but plugged back to Bethel sandstone.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	County	Location: Sec. Survey	Location: Twp. Lat.	Location: Rge. Long.	Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day: Oil, U.S. Bbl.	Initial Production per Day: Gas, Millions Cu. Ft.	Remarks	Field Name of New Discoveries and Extensions
197	McDonough..	2	5 N	4 W	820	"Trenton"	Ed Jones et al.			Dry	
198	McDonough..	6	4 N	4 W	483	Hoing	W. I. Cole			Dry	
199	McDonough..	6	4 N	4 W	510	Hoing	W. I. Cole			Dry	
200	McDonough..	15	7 N	3 W	815	"Trenton"	John Mehmken			Dry	
201	McDonough..	6	4 N	4 W	511	Hoing	W. I. Cole et al.			Dry	
202	Macon.......	30	17 N	2 E	2,992	St. Peter	Sun Oil Co.			Dry	
203	Macon.......	3	15 N	2 E	1,085	Chester	Werner Bros.			Dry	
204	Macoupin....	15	8 N	8 W	425	Pennsylvanian	American Petroleum Corp.		0.62[3]		
205	Macoupin....	8	9 N	7 W	448	B. Pennsylvanian	Cross et al.			Dry	
206	Macoupin....	21	9 N	8 W	500	L. Mississippian	Erie Drilling Co.			Dry	
207	Macoupin....	33	9 N	6 W	617	B. Pennsylvanian	Erie Drilling Co.			Dry	
208	Macoupin....	24	8 N	9 W	1,755	"Trenton"	Spence Bros. et al.			Dry	
209	Macoupin....	23	9 N	8 W	420	Pennsylvanian	E. McCallum et al.			Dry	
210	Macoupin....	15	11 N	8 W	1,828	Trenton	Phillips Petroleum Co.			Dry	
211	Madison.....	12	4 N	9 W	2,093	St. Peter	Penn-Illinois Oil Co.			Dry	
212	Madison.....	15	6 N	8 W	1,980	"Trenton"	Marshall Spivey			Dry	
213	Madison.....	9	4 N	8 W	1,080	L. Mississippian	C & A Development Co.			Dry	
214	Madison.....	18	4 N	8 W	400	Mississippian	Penn-Ill. Development Co.			Dry	
215	Marion......	35	3 N	4 E	2,765	L. Mississippian	Helmrich and Payne			Dry	
216	Marion......	12	4 N	1 E	1,962	Ste. Genevieve	Schriver et al.			Dry	
217	Marion......	5	3 N	1 E	1,494	B. Chester	Alexander et al.			Dry	
218	Marion......	29	2 N	1 E	2,001	St. Louis	W. C. McBride, Inc.			Dry	
219	Marion......	12	4 N	4 E	2,881	St. Louis	Albachtin and Sims			Dry	
220	Marion......	33	2 N	1 E	2,007	L. Mississippian	W. D. Sheddon et al.			Dry	
221	Marion......	36	4 N	1 E	1,050	B. Pennsylvanian	Hackman and Harris			Dry	
222	Marion......	1	3 N	1 E	1,759	Bethel	Vaughn et al.			Dry	
223	Marion......	7	3 N	1 E	1,514	L. Chester	Adams			Dry	
224	Marion......	27	1 N	1 E	1,950	Bethel	Samuel and Dyke			Dry	
225	Marion......	5	1 N	2 E	1,916	"McClosky"	Texas Company	732			Lake Centralia-Salem field
226	Marion......	5	3 N	2 E	2,000	Bethel	Max Conrey et al.			Dry	
227	Marion......	24	1 N	1 E	2,200	Ste. Genevieve	A. P. Potter et al.			Dry	
228	Marion......	19	2 N	1 E	2,100	L. Mississippian	Morrison			Dry	
229	Marion......	22	4 N	2 E	2,265	Ste. Genevieve	Penn-Illinois Oil and Gas			Dry	
230	Marion......	18	3 N	3 E	2,230	Bethel	Marion Oil Co.			Dry	
231	Marion......	2	1 N	1 E	2,194	Ste. Genevieve	Harris and Broddus			Dry	
232	Marion......	7	1 N	1 E	1,820	L. Mississippian	J. O. Gill			Dry	
233	Marion......	9	1 N	1 E	1,930	Ste. Genevieve	Parshall-Graham			Dry	
234	Marion......	1	1 N	1 E	1,728	Golconda	Iroquois Oil & Gas Co.			Dry	
235	Marion......	5	1 N	1 E	1,823	Bethel	Ann Bell Oil Co.			Dry	
236	Marion......	8	1 N	1 E	2,045	Ste. Genevieve	Thompson Drilling Co.			Dry	
237	Marion......	25	2 N	1 E	2,018	Bethel	Carpenter & Goldberg			Dry	
238	Marion......	36	2 N	1 E	1,920	Bethel	Boyce & Welch			Dry	
239	Marion......	18	2 N	4 E	2,801	Ste. Genevieve	Bonnie Oil & Gas Co.			Dry	
240	Marion......	2	1 N	1 E	900	Pennsylvanian	Blalack & Gray			Dry	
241	Marion......	3	1 N	1 E	1,632	Cypress	Ann Bell Oil Co.			Dry	
242	Marion......	5	1 N	1 E	837	Pennsylvanian	Cole & Simmel			Dry	

[3] Gas well for local use.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	County	Location: Sec. Survey	Location: Twp. Lat.	Location: Rge. Long.	Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day: Oil, U.S. Bbl.	Initial Production per Day: Gas, Millions Cu. Ft.	Remarks	Field Name of New Discoveries and Extensions
243	Marion......	12	1 N	1 E	2,026	Paint Creek	J. L. Gardenhire			Dry	
244	Marion......	10	1 N	3 E	2,133	Chester	Cattani et al.			Dry	
245	Marion......	19	1 N	3 E	2,303	L. Chester	R. E. Dalton Oil Co.			Dry	
246	Marion......	10	2 N	1 E	1,710	L. Chester	Boyce et al.			Dry	
247	Marion......	11	3 N	2 E	2,331	"McClosky"	Baldwin & Streetor			Dry	
248	Marion......	23	3 N	2 E	2,453	Ste. Genevieve	Max Pray			Dry	
249	Marion......	20	4 N	2 E	1,652	L. Chester	Newman et al.			Dry	
250	Marion......	22	4 N	2 E	1,550	L. Chester	Wigoso Oil & Gas Co.			Dry	
251	Marion......	12	1 N	1 E	2,315	Bethel	Blair et al.			Dry	
252	Marion......	30	1 N	2 E	1,835	Golconda	Tom Boyce			Dry	
253	Marion......	15	1 N	4 E	2,680	B. Chester	Dalton Oil Development Co.			Dry	
254	Marion......	1	2 N	1 E	2,131	Ste. Genevieve	Richland Corp.			Dry	
255	Marion......	5	2 N	2 E	2,195	Ste. Genevieve	Mid Valley Steel Co.			Dry	
256	Marion......	5	2 N	2 E	2,192	"McClosky"	W. S. Tatum			Dry	
257	Marion......	6	2 N	4 E	2,850	Ste. Genevieve	Garnier Bros.			Dry	
258	Marion......	24	3 N	3 E	2,560	St. Louis	Devonian Oil Co.			Dry	
259	Marion......	24	4 N	2 E	2,005	Bethel	Transwestern Oil Co.			Dry	
260	Marion......	26	4 N	2 E	2,211	"McClosky"	Conrey et al.			Dry	
261	Marion......	1	1 N	1 E	2,202	Ste. Genevieve	J. J. Broadus			Dry	
262	Marion......	16	1 N	1 E	1,910	Bethel	Dr. Phillips & Ashby			Dry	
263	Marion......	8	2 N	2 E	2,261	Ste. Genevieve	Ed Hollmans et al.			Dry	
264	Marion......	20	2 N	3 E	2,501	Ste. Genevieve	Pyramid Petroleum Corp.			Dry	
265	Marion......	16	3 N	2 E	2,351	Ste. Genevieve	Bob Garland			Dry	
266	Menard......	24	19 N	5 W	1,570	"Niagaran"	Scroggins et al.			Dry	
267	Monroe......	10	3 S	11 W	780	St. Peter	Fernwald et al.			Dry	
268	Montgomery.	29	8 N	5 W	849	St. Louis	Bill Casseday			Dry	
269	Montgomery.	4	8 N	5 W	821	L. Mississippian	Baker et al.			Dry	
270	Montgomery.	29	8 N	5 W	905	Pennsylvanian	Meyers et al.		0.08[4]		
271	Montgomery.	3	8 N	5 W	758	B. Pennsylvanian	Baker & Martin			Dry	
272	Montgomery.	4	9 N	4 W	1,250	Ste. Genevieve	Joe Kesl			Dry	
273	Montgomery.	10	10 N	1 W	1,610	Bethel	Swords et al.			Dry	
274	Montgomery.	32	8 N	5 W	700	B. Pennsylvanian	Meyers & Graham			Dry	
275	Morgan......	8	15 N	9 W	440	Warsaw	Judd & Sons			Dry	
276	Morgan......	33	14 N	8 W	1,685	Trenton	Waverly Oil Syndicate, Ltd.			Dry	
277	Morgan......	25	15 N	9 W	1,590	Trenton	Alexander Oil Co.			Dry	
278	Morgan......	25	15 N	9 W	450	L. Mississippian	Alexander Oil Co.			Dry	
279	Moultrie.....	18	13 N	6 E	2,005	St. Louis	Ralph Neely et al.			Dry	
280	Moultrie.....	22	15 N	6 E	1,866	Bethel	Continental Oil Co.			Dry	
281	Perry........	10	6 S	3 W	1,643	Ste. Genevieve	Amerada Petrol. Co.			Dry	
282	Perry........	22	6 S	2 W	1,769	Ste. Genevieve	Amerada Petrol. Co.			Dry	
283	Perry........	17	6 S	1 W	1,832	St. Louis	Eason Oil Co.			Dry	
284	Perry........	6	5 S	1 W	1,605	Ste. Genevieve	L. C. Simmel			Dry	
285	Perry........	27	5 S	1 W	2,636	Ste. Genevieve	Bert Fields & Rockhill Co.			Dry	
286	Piatt........	17	18 N	6 E	3,021	"Trenton"	Max Pray et al.			Dry	
287	Pope.........	12	11 S	5 E	1,760	Chester	C. C. Whitlock et al.			Dry	
288	Randolph....	3	4 S	5 W	3,640	Joachim	Mabee et al.			Dry	
289	Randolph....	28	6 S	6 W	716	L. Mississippian	Pioneer Oil and Gas Co.			Dry	
290	Randolph....	4	5 S	6 W	350	Chester	S. B. Schlosburg			Dry	

[4] Gas well for local use.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	County	Location			Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks	Field Name of New Discoveries and Extensions
		Sec. Survey	Twp. Lat.	Rge. Long.				Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		
291	Randolph....	29	4 S	7 W	508	L. Mississippian	Dr. Seward et al.			Dry	
292	Randolph....	12	5 S	9 W	1,910	St. Peter	Ames Drilling Co.			Dry	
293	Richland.....	21	3 N	9 E	3,121	"McClosky sand"	Max Pray et al.	139			Noble extension
294	Richland.....	28	3 N	9 E	3,064	Ste. Genevieve	Mammoth Prod. & Refiners	2,192			Noble extension
295	Richland.....	5	3 N	10 E	3,124	Ste. Genevieve	Papoose Oil Co.			Dry	
296	Richland.....	2	4 N	10 E	3,158	St. Louis	Gulf Oil Co.			Dry	
297	Richland.....	34	4 N	10 E	3,099	Ste. Genevieve	Morrison and German			Dry	
298	Richland.....	29	4 N	9 E	3,180	Ste. Genevieve	American Exploration Co.			Dry	
299	Richland.....	26	4 N	10 E	3,036	"McClosky"	Pyramid Petrol. Corp.	1,000			Olney
300	Richland.....	23	3 N	9 E	3,080	"McClosky"	American Nat'l Drill. Co.	20			Noble extension
301	Richland.....	7	2 N	9 E	2,984	"McClosky"	J. V. Wicklund	1,053			Schnell
302	Richland.....	26	4 N	9 E	2,929	Cypress	Pure Oil Co.	514			Noble extension
303	Richland.....	21	4 N	10 E	3,208	Ste. Genevieve	Wicklund Development			Dry	
304	Richland.....	35	4 N	10 E	3,141	Ste. Genevieve	Kingwood Oil Co.			Dry	
305	St. Clair.....	27	1 N	10 W	472	"Trenton"	Pioneer Oil & Gas Co.	100			Dupo extension
306	St. Clair.....	27	1 N	10 W	523	"Trenton"	Pioneer Oil & Gas Co.	65			Dupo extension
307	St. Clair.....	13	2 S	6 W	1,012	Ste. Genevieve	Group Oil Corp.			Dry	
308	St. Clair.....	20	2 N	6 W	1,023	St. Louis	Neil et al.			Dry	
309	St. Clair.....	31	1 S	7 W	1,234	L. Mississippian	Mossbaugh			Dry	
310	St. Clair.....	28	3 S	6 W	895	L. Mississippian	Group Oil Co.			Dry	
311	Saline.......	3	10 S	6 E	1,502	L. Chester	W. J. Rodgers et al.			Dry	
312	Saline.......	12	8 S	6 E	360	Pennsylvanian	C. F. Bolton			Dry	
313	Saline.......	13	9 S	7 E	2,601	L. Mississippian	Bolton et al.			Dry	
314	Sangamon....	24	15 N	7 W	2,257	St. Peter	Walter Wittlinger			Dry	
315	Schuyler.....	27	2 N	1 W	850	"Niagaran"	O. D. Arnold et al.			Dry	
316	Shelby.......	19	10 N	4 E	2,012	Ste. Genevieve	Whisenant and Henshaw			Dry	
317	Shelby.......	4	11 N	3 E	1,951	Ste. Genevieve	Milan et al.			Dry	
318	Shelby.......	27	12 N	3 E	1,804	Ste. Genevieve	Cypress Oil & Gas Co.			Dry	
319	Shelby.......	25	11 N	2 E	1,886	Ste. Genevieve	Borah et al.			Dry	
320	Shelby.......	17	12 N	4 E	2,072	St. Louis	Kingwood Oil Co.			Dry	
321	Shelby.......	16	12 N	4 E	1,921	Ste. Genevieve	Simar Oil Co.			Dry	
322	Shelby.......	30	12 N	4 E	1,865	Bethel	O. J. Connell			Dry	
323	Shelby.......	9	9 N	3 E	2,008	Ste. Genevieve	A. A. Baker			Dry	
324	Shelby.......	15	9 N	3 E	1,716	Bethel	Paul Braner et al.			Dry	
325	Shelby.......	4	9 N	3 E	1,677	Bethel	Roy T. Moore & Black			Dry	
326	Shelby.......	24	10 N	3 E	1,702	Cypress	Dan Moore et al.			Dry	
327	Shelby.......	26	10 N	4 E	1,900	Basal Chester	Ogg & Joly			Dry	
328	Shelby.......	32	10 N	4 E	1,920	Ste. Genevieve	Black et al.			Dry	
329	Shelby.......	1	9 N	4 E	2,129	St. Louis	Kingwood Oil Co.			Dry	
330	Shelby.......	3	10 N	5 E	2,175	Ste. Genevieve	Jackson & Fisher			Dry	
331	Shelby.......	8	12 N	2 E	2,094	L. Mississippian	W. S. Tatum			Dry	
332	Shelby.......	34	12 N	4 E	2,012	"McClosky"	Prunty Producing Co.			Dry	
333	Vermilion....	13	18 N	14 W	1,430	"Niagaran"	A. M. Meyers et al.			Dry	
334	Wabash......	25	1 S	13 W	2,635	Ste. Genevieve	Hayes & Myer			Dry	
335	Wabash......	28	1 N	12 W	1,501	Biehl	Cecil Kneipp et al.			Dry	
336	Wabash......	9	1 S	12 W	1,515	Biehl	Myers et al.			Dry	
337	Wabash......	31	1 N	12 W	2,408	L. Mississippian	Harry T. Martin			Dry	
338	Wabash......	12	1 N	13 W	1,753	B. Pennsylvanian	Charles Foreman			Dry	
339	Wabash......	13	1 S	13 W	3,500	L. Mississippian	Guilde & Jones			Dry	
340	Warren......	35	12 N	1 W	495	"Niagaran"	W. C. & W. Co.			Dry	

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	County	Location Sec. Survey	Twp. Lat.	Rge. Long.	Total Depth, Ft.	Deepest Horizon Tested	Drilled by	Initial Production per Day Oil, U.S. Bbl.	Gas, Millions Cu. Ft.	Remarks	Field Name of New Discoveries and Extensions
341	Warren......	26	8 N	1 W	875	"Trenton"	L. E. Ketcherside et al.			Dry	
342	Washington..	28	1 S	4 W	1,087	Bethel	Frost, Vickers & Patton			Dry	
343	Washington..	16	3 S	2 W	1,426	B. Chester	B. D. Bitterman et al.			Dry	
344	Washington..	22	1 S	1 W	1,925	L. Mississippian	Parshall-Graham Oil Co.			Dry	
345	Washington..	8	1 S	3 W	1,499	L. Mississippian	Cox et al.			Dry	
346	Washington..	4	2 S	5 W	1,238	L. Mississippian	Morris et al.			Dry	
347	Washington..	11	1 S	1 W	1,030	B. Pennsylvanian	Salvage Oil & Fuel Co.			Dry	
348	Washington..	6	3 S	2 W	1,443	Bethel	S. Townsend et al.			Dry	
349	Washington..	25	1 N	1 W	1,425	L. Chester	C. E. Phelps			Dry	
350	Washington..	31	1 N	2 W	1,715	L. Mississippian	Schlafly et al.			Dry	
351	Washington..	33	1 S	5 W	900	Bethel	G. A. Morris			Dry	
352	Washington..	19	1 S	5 W	1,683	Ste. Genevieve	Thompson Drilling Co.			Dry	
353	Washington..	30	1 S	5 W	1,422	Bethel	Venture Oil Co.			Dry	
354	Washington..	16	3 S	2 W	1,618	Ste. Genevieve	Bitterman et al.			Dry	
355	Washington..	29	3 S	5 W	1,517	L. Mississippian	E. C. Lang			Dry	
356	Washington..	12	1 S	1 W	1,680	Bethel	Morris et al.			Dry	
357	Washington..	7	2 S	3 W	1,475	Ste. Genevieve	Hall et al			Dry	
358	Washington..	19	3 S	1 W	3,537	Bethel	Thompson Drilling Co.			Dry	
359	Washington..	12	1 S	3 W	1,551	Ste. Genevieve	L. J. Gordon			Dry	
360	Washington..	10	3 S	4 W	1,373	St. Louis	J. B. Oberholtzer			Dry	
361	Wayne......	16	3 S	7 E	3,287	"McClosky"	Texas Oil Co.	400			Aden
362	Wayne......	14	1 N	9 E	3,273	Ste. Genevieve	B. C. Morrison			Dry	
363	Wayne......	21	1 N	5 E	3,200	Ste. Genevieve	Tarpon (Kennova) Oil Co.			Dry	
364	Wayne......	30	1 S	5 E	3,250	L. Mississippian	Gulf Refining Co.			Dry	
365	Wayne......	33	2 S	7 E	3,325	"McClosky"	H. H. Weinert, Inc.	400			North Aden
366	Wayne......	16	3 S	9 E	3,438	"McClosky"	Iroquois Oil & Gas Co.	150			Leech Twp.
367	Wayne......	21	2 S	7 E	3,443	Ste. Genevieve	H. H. Weinert, Inc.			Dry	
368	Wayne......	8	2 S	8 E	3,394	"McClosky"	Ed Martin & Stokes			Dry	
369	Wayne......	8	3 S	9 E	3,500	Ste. Genevieve	Al Stengle et al.			Dry	
370	Wayne......	33	1 S	7 E	3,336	Ste. Genevieve	Roche & Voyles			Dry	
371	Wayne......	2	1 S	8 E	3,100	Ste. Genevieve	A. P. Muhlbach	48			Mt. Erie
372	Wayne......	4	2 S	7 E	3,269	Ste. Genevieve	Roche & Voyles	401			Boyleston
373	White........	26	5 S	9 E	3,210	Ste. Genevieve	Mazda Oil Corp.			Dry	
374	White........	3	5 S	9 E	3,408	Ste. Genevieve	Palmer Corp.			Dry	
375	White........	12	7 S	8 E	3,065	Ste. Genevieve	Arab Petroleum Co.			Dry	
376	White........	12	4 S	9 E	3,919	Salem	Sun Oil Co.			Dry	
377	Williamson...	4	10 S	2 E	2,100	Ste. Genevieve	Ge-Lo Oil Syndicate			Dry	

	In Proven Fields	Wildcats*
Number of wells drilling Dec. 31, 1938..................................	280	91
Number of oil wells completed during 1938..............................	1,959	25
Number of gas wells completed during 1938..............................	20	6
Number of dry holes completed during 1938..............................	170	359

* One-fourth mile or more from production.

TABLE 3.—*Summary of Drilling and Initial Production in Illinois for* 1938

County	Number of Wells Drilled in 1938			Total Initial Production		Footage Drilled in 1938	
	Total Completed	Total Producing Oil	Total Producing Gas	Oil, Bbl.	Gas, Millions Cu. Ft.	Total	Producing Wells
Bond	12	1	1	15	0.1	20,292	2,779
Brown	2	0	0	0	0.0	1,215	0
Bureau	2	0	0	0	0.0	1,797	0
Cass	1	0	0	0	0.0	585	0
Champaign	5	0	2[2]	0	1.6	3,305	0
Christian	4	0	0	0	0.0	5,595	0
Clark	24	7	3[2]	111	0.9	17,585	4,607
Clay	153	141	0	65,970	0.0	469,074	430,398
Clinton	444	398	0	54,228	0.0	610,632	542,219
Coles	7	0	0	0	0.0	14,740	0
Crawford	19[1]	7	1[2]	32	0.3	23,717	9,801
Cumberland	5	0	0	0	0.0	12,547	0
Edgar	5	0	0	0	0.0	6,688	0
Effingham	8	0	0	0	0.0	22,240	0
Fayette	575	509	1[2]	117,094	4.0[4]	910,818	804,573
Franklin	6	0	0	0	0.0	657	0
Fulton	1	0	0	0	0.0	18,706	0
Hamilton	1	0	0	0	0.0	3,460	0
Hancock	2	0	0	0	0.0	1,099	0
Hardin	1	0	0	0	0.0	2,345	0
Iroquois	1	0	0	0	0.0	1,096	0
Jackson	3	0	0	0	0.0	8,042	0
Jasper	6	0	0	0	0.0	15,609	0
Jefferson	68	40	0	9,031		148,432	82,099
Lawrence	36	10	15[3]	342	151.0	48,666	33,543
McDonough	7	2	0	3	0.0	4,008	869
Macon	2	0	0	0	0.0	4,077	0
Macoupin	9	0	2[2]	0	1.4	6,983	865
Madison	4	0	0	0	0.0	5,553	0
Marion	729	643	0	191,766	0.8[4]	1,258,330	1,096,453
Menard	1	0	0	0	0.0	1,570	0
Monroe	1	0	0	0	0.0	780	0
Montgomery	7	0	1[2]	0	0.1	6,893	905
Morgan	4	0	0	0	0.0	4,165	0
Moultrie	2	0	0	0	0.0	3,871	0
Perry	5	0	0	0	0.0	9,485	0
Piatt	1	0	0	0	0.0	3,021	0
Pope	1	0	0	0	0.0	1,760	0
Randolph	5	0	0	0	0.0	7,124	0
Richland	180	135	0	68,825	0.0	560,371	412,661
St. Clair	11	5	0	745	0.0	7,787	3,623
Saline	4	0	0	0	0.0	4,463	0
Sangamon	1	0	0	0	0.0	2,257	0
Schuyler	1	0	0	0	0.0	850	0
Shelby	17	0	0	0	0.0	32,844	0
Vermilion	1	0	0	0	0.0	1,430	0
Wabash	23	6	0	225	0.0	38,627	9,328
Warren	2	0	0	0	0.0	1,370	0
Washington	19	0	0	0	0.0	29,544	0
Wayne	107	80	0	35,571	0.0	334,740	246,673
White	4	0	0	0	0.0	13,602	0
Williamson	1	0	0	0	0.0	2,100	0
Total	2,539	1,984	26	543,958	160.2	4,766,047	3,677,373

[1] Includes two pressure wells.

[2] Gas used on the lease and for local heating and lighting.

[3] Two wells producing gas, which is used on the lease.

[4] Gas produced with the oil.

TABLE 4.—*Total Initial Production of Wells Drilled in New Fields for* 1938

Field	Barrels	Field	Barrels	Field	Barrels
Patoka	980	Dix	8,143	St. James	3,638
Clay City	70,786	Aden	1,165	Roaches	464
Rinard	0	Flora	2,101	Elk Prairie	20
Noble	51,996	Schnell	2,663	Sorento	15
Cisne	12,013	Lake Centralia-Salem	165,588	Boyleston	1,203
Centralia (New)	78,157	Ina	200	Marcoe	204
Beecher City-Louden	113,456	North Aden	19,435	Mt. Erie	48
Olney	14,166	Leech Township	459	Total	546,900

TABLE 5.—*Wells in the New Fields, December* 31, 1938

Field, *County*	Producing Wells	Dry Holes[1]	Drilling Wells	Rigs Standing	Rigging Up	Locations	Acres
Patoka, *Marion*	104[2]	20	0	0	0	0	465
Clay City, *Clay, Wayne*	222	16	3	7	1	3	4,750
Rinard, *Wayne*	1	2	0	3	0	1	10
Noble, *Richland*	145[3]	29	0	2	1	0	3,150
Cisne, *Wayne*	25	6	3	0	1	1	575
Centralia (New), *Clinton, Marion*	526	36	3	15	1	1	2,000
Beecher City-Louden, *Fayette*	488	25	17	67	12	2	15,860
Olney, *Richland*	30	11	2	1	0	0	380
Dix, *Jefferson*	35	0	1	1	0	0	615
Aden, *Wayne*	4	2	0	0	0	0	160
Flora, *Clay*	9	2	2	3	0	0	140
Schnell, *Richland*	4	5	0	0	0	0	40
Lake Centralia-Salem, *Marion*	480	17	24	97	11	23	7,520
Ina, *Jefferson*	1	2	0	0	0	0	10
North Aden, *Wayne*	40	4	1	3	1	2	690
Leech Township., *Wayne*	2	0	0	0	3	0	20
St. James, *Fayette*	24	0	4	3	0	3	270
Roaches, *Jefferson*	2	0	1	2	0	1	20
Elk Prairie, *Jefferson*	1	0	0	0	0	0	10
Sorento, *Bond*	1	0	0	0	0	0	10
Boyleston, *Wayne*	1	0	2	0	0	0	10
Marcoe, *Jefferson*	1	0	0	0	0	0	10
Mt. Erie, *Wayne*	1	0	0	0	0	0	10
Russellville (gas), *Lawrence*	15	5	0	2	0	1	500
	2,157	182	63	206	31	38	37,225

[1] Within ¼ mile of production.
[2] Eleven producing wells were abandoned during 1938.
[3] Eight producing wells were abandoned during 1938.

TABLE 6.—*Discovery Wells of the New Fields and Extensions in Illinois for 1938*

Field	County	Company, Well and Location	Total Depth, Ft.	Producing Formation				
				Depth, Ft.	Name	Initial Production, Bbl.	Type of Discovery	Date of Completion of Discovery Well
North Olney	Richland	Pyramid Oil Co., University of Chicago 1, NW NW NW 26-4N-10E	3,036	3,030	McClosky	1,000	Field	5-4-38
Dix	Jefferson	Carter Oil Co., Tate 1, C W NW NE 10-1S-2E	1,990	1,980	Bethel	58	Field	1-2-38
Aden	Wayne	Texas Co., Silverman 1, C E SW NW 16-3S-7E	3,287	3,276	McClosky	385	Field	1-15-38
North Aden	Wayne	H. H. Weinert, Inc., Twist 1, NE NW SW 33-2S-7E	3,325	3,308	McClosky	400	Field	7-27-38
Flora	Clay	Kingwood Oil Co., Graham 1, C S SW NE 13-3N-6E	2,983	2,973	McClosky	275	Field	6-22-38
Flora	Clay	Ohio Oil Co., Hardy 1, NW SE SE 9-3N-7E	2,967	2,958	McClosky	459	Extension	7-20-38
Schnell	Richland	Wicklund Development Co., McCauley 1B, NE SW NW 7-2N-9E	2,996	2,980	McClosky	1,053	Field	6-22-38
Lake Centralia-Salem	Marion	Texas Co., Tate 1, NW NW 5-1N-2E	1,810	1,692	Bethel	732	Field	7-6-38
Ina	Jefferson	Nollem Oil & Gas Co., Benoist-Kelley 1, NE NW NE 25-4S-2E	3,007	3,002	St. Louis	200	Field	7-27-38
St. James	Fayette	Rosenthal et al, Washburn 1, NE SE NW 30-6N-3E	1,622	1,600	Cypress	188	Field	9-14-38
Leech Township	Wayne	Iroquois Oil & Gas., Walker 1, C NW NW NW 16-3S-9E	3,438	3,428	McClosky	150	Field	9-14-38
Roaches	Jefferson	Magnolia Petroleum Co., Harvey 1, NW NE SW 22-2S-1E	2,263	2,239	McClosky, Rosiclare	217	Field	11-29-38
Elk Prairie	Jefferson	Benedum-Trees, Jefferson Oil & Gas 1, C NW NE 16-4S-2E	2,751	2,718	McClosky	25	Field	11-9-38
Boyleston	Wayne	Roche & Boyles, McPherson 1, C S SE NE 4-2S-7E	3,269	3,253	McClosky	400	Field	12-13-38
North Noble	Richland	Pure Oil Co., Wakefield 1, C W NW NE 26-4N-9E	2,583	2,564	Cypress	514	Extension	10-11-38
West Clay City	Clay	Wiser Oil Co., Irwin 1, C N SE NW 12-2N-7E	3,076	3,060	McClosky	273	Extension	1-19-38
Russellville (gas)	Lawrence	Kesl et al. Gray 1, C N NW NE 13-4N-11W	1,061	1,060	Buchanan	2,651[1]	Field	7-23-38
Sorento	Bond	De Mayo et al, Dressor 1, SW NE NW 21-6N-4W	1,830	1,800	Niagaran	15	Field	12-5-38
Marcoe	Jefferson	Magnolia Petroleum Co., Dare 1, SE SW NE 22-3S-2E	2,765	2,746	McClosky	237	Field	12-24-38
Mt. Erie	Wayne	Mulbach, Anderson 1, NW NW NW 2-1S-8E	3,092	3,080	McClosky	48	Field	12-31-38
Clay City	Clay	Danville Oil Drillers, Inc., C. D. Duff 1, NE SE NE 19-3N-8E	3,047	3,016	McClosky	124	Extension	1-10-38
Clay City	Clay	Wiser Oil Co., Irwin 1, C N SE NW 12-2N-7E	3,076	3,012	McClosky	273	Extension	1-19-38
Centralia	Clinton	Adams Oil & Gas Co., Hefter 1, SE NE 13-1N-1W	1,370	1,350	Bethel	275	Extension	2-9-38
Beecher City-Louden	Fayette	Farelly et al. H. Lilley 1, SE SW SE 16-8N-3E	1,573	1,561	Bethel	35	Extension	5-25-38
Noble	Richland	Max Pray et al. Runyon 1, SW SW SE 21-3N-9E	3,121	3,036	McClosky	139	Extension	2-15-38
Noble	Richland	Mammoth Producers & Refiners, Bell 1, NW NE SW 28-3N-9E	3,064	3,026	McClosky	2,162[2]	Extension	2-15-38
Noble	Richland	American National Drilling Co., Everson 1, NE NE SE 23-3N-9E	3,080	3,043	McClosky	20	Extension	5-25-38

[1] Thousands of cubic feet.
[2] Estimated.

TABLE 7.—*Completions and Production in Illinois from January 1, 1937 to December 31, 1938*

Date	Completions	Number of Producing Wells	Production, Thousands of Barrels		
			New Fields	Old Fields[1]	Total[2]
1937					
January	5	1		368	368
February	6	6		343	343
March	9	5		410	410
April	15	8		386	386
May	14	10		416	416
June	22	16	53	410	463
July	27	18	120	410	530
August	49	31	266	408	674
September	92	63	452	397	849
October	76	56	520	392	912
November	73	41	592	398	990
December	61	37	755	330	1,085
	449	292	2,884[3]	4,542	7,426
1938					
January	57	40	809	319	1,128
February	59	35	778	330	1,108
March	107	82	918	412	1,330
April	89	71	1,061	327	1,388
May	122	107	1,076	364	1,440
June	192	147	1,093	369	1,462
July	176	136	1,284	358	1,642
August	207	149	1,691	371	2,062
September	255	199	2,194	359	2,553
October	431	345	2,431	337	2,768
November	394	330	2,722	345	3,067
December	452	369	3,608	373	3,981
	2,541	2,010	19,665	4,264	23,929

[1] Difference between total production for the new fields and the U. S. Bureau of Mines total.

[2] The figures in the total production are from the U. S. Bureau of Mines. Other figures are from various sources.

[3] This figure is greater than the total by months because monthly production figures from the new fields were not available until June 1937.

Gas was first discovered in the vicinity of Russellville, Ill., in northeastern Lawrence County, on March 17, 1937. The Warren Hastings et al., Lagow No. 1A, drilled in sec. 30, T. 5 N., R. 10 W., obtained production in a Pennsylvanian sandstone at a depth of 619 ft. The initial production was 824,000 cu. ft. Another producing well was drilled in the same section a short time later and four dry holes were drilled offsetting the two producers. The Kentucky Natural Gas Corporation

of Owensboro, Ky., constructed a 3-in. line from the Oaktown, Ind., gas field to take the gas from these wells.

In July 1938, the Joe Kesl et al., Scott Gray No. 1, drilled in sec. 13, T. 4 N., R. 11 W., obtained production in the Buchanan sandstone at a depth of 1061 ft. The initial production was 2,651,000 cu. ft. The well was deepened a few feet in the sand and the production was increased to 16,000,000 cu. ft. Thirteen producing wells were drilled in the field during 1938, and drilling activity is still continuing. The highest initial productions were from 20 to 30 million cubic feet and the average for all of the wells was 14 million. The present field includes the N½ of sec. 13, the S½ of sec. 12, T. 4 N., R. 11 W., and the SW¼ of sec. 7, T. 4 N., R. 10 W. Deeper potential oil-producing and gas-producing formations have not been tested in the field. The northwest edge of the field has been fairly well defined by three dry holes. The proven acreage in both fields at the end of the year totaled 500.

The Kentucky Natural Gas Corporation during 1938 replaced the 3-in. line from Oaktown to sec. 30, T. 5 N., R. 10 W., with a 6-in. line, and constructed two 4-in. lines to the Buchanan sand field.

An analysis of the gas from the north field shows that the gas is composed mainly of methane with only a trace of ethane, less than 1 per cent carbon dioxide and a small percentage of nitrogen. The gas from the south field is also composed largely of methane with a small percentage of ethane, nitrogen and carbon dioxide. The B.t.u. value of both gases is approximately 950 per cubic foot.

Improved Recovery Methods

Repressuring.—Little new work was undertaken by the oil companies during 1938 to increase recovery of oil in the old fields of Illinois. Practically all of the previous repressuring plants were continued in operation.

In the Carlyle pool, Clinton County, a water-flooding operation was discontinued in October 1937, and air repressuring started, using the same input wells previously used for water in December 1937. Continuous operation of the pressure plant began in February 1938.

In the Louden (Beecher City) field the Carter Oil Co. has undertaken pressure maintenance with gas produced from their leases in sec. 15, T. 8 N., R. 3 E. Five input wells were drilled in the section (five-spot). Both the Cypress and Bethel sands are repressured in each well. A packer is set below the Cypress sand and the gas to the Bethel sand passes through tubing, whereas that to the Cypress is from the casing. The casing is perforated for both sands. The project is just getting started and no results have been noticed, as the adjacent producing wells are prorated. An average of about 15,000 cu. ft. of gas is injected into each sand per day. Two 300-hp. compressors are being used.

It is reported that a similar pressure-maintenance project is planned by some of the operators in the Salem pool.

Acidization.—Ten acidizations were reported in the old southeastern field, of which seven yielded substantial increases in production and three yielded no increase. Acidizing is standard practice in completing wells in the central basin fields producing from the McClosky.

Petroleum Conference

The sixth annual conference of the Illinois-Indiana Petroleum Association was held at Robinson, June 4, 1938, and was attended by more than 400 persons. The technical sessions included papers on geology and field operating problems.

Outlook

Drilling development exceeding that of 1938 may be expected in 1939. Multiple sand production is proved in the Salem and Louden fields, which will require the drilling of many additional wells. The large amount of wildcat drilling will doubtless result in numerous discoveries of new fields in 1939.

Acknowledgments

The writer is indebted to many companies and individuals for furnishing data used in this report. The principal work of compiling the statistical data presented herein was done by Dr. George V. Cohee, assisted by Dr. Charles W. Carter and Mr. James L. Carlton, all of the Survey staff.

Oil and Gas Developments in Indiana during 1938

By Ralph E. Esarey* and G. F. Fix†

(New York Meeting, February, 1939)

The oil and gas industry in Indiana in 1938 showed considerable improvement over the preceding year. Most of the drilling and development during the year, as in the past several years, was in the Indiana portion of the Illinois Basin, but increasing interest was apparent in the old Trenton area, for possibilities of further production in the Trenton formation and the underlying St. Peter sandstone. Interest in all other portions of the state was at a new peak, since many areas have never been prospected. Natural gas production continued to drop during 1938, since new discoveries have not been able to keep pace with the rapid decline in older areas. Oil production increased considerably, chiefly through the discovery of new fields. Older fields contributed about the same quantity of oil during 1938 as during the preceding year.

There were 159 wells completed in Indiana during 1938, an increase of 25 over the preceding year. Of these, 48 were oil wells, 41 were gas, and 70 failed to find commercial production. Forty-three, or about 20 per cent, were wildcat. Six of these were productive—three oil wells and three gas wells. Thirty-nine wells on which operations started during the year had not been completed by Dec. 31. Fourteen others were temporarily abandoned, with the possibility that several will be drilled to completion in the near future. A new oil field (Heusler) was discovered in May 1938, in secs. 1 and 12, T. 7 S., R. 12 W., Posey County. Production was found in the Waltersburg (Upper Chester) sandstone at a depth of approximately 1775 ft. At the close of the year, Heusler field had nine producing wells and two drilling. The Point township area, Posey County, near the confluence of the Wabash and Ohio Rivers, held promise of good production from the McClosky lime, but offsets to the discovery well had only shows of oil. The discovery well declined rapidly in production and was finally plugged. In the Oaktown field, Knox County, a wildcat came in with a good flow of gas, extending the field to the east, and proving considerably more acreage. A new gas area was discovered in Sullivan County, and four good wells were completed. The discovery well was in sec. 35, T. 8 N., R. 10 W., and had an initial

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production of 2000 M cu. ft. per day from a depth of 821 ft. A test well, drilled to a depth of 1597 ft. in the center of Sullivan County's shallow production, made a good oil well in the Salem limestone. This is the first commercial production in the state from that formation. The outstanding development of the year was the discovery of the Griffin field in western Gibson County. The discovery well was drilled in sec. 13, T. 3 S., R. 14 W., to the McClosky at a depth of 2876 ft. Although the well has not been accurately gauged, because of inadequate storage, its

TABLE 1.—*Oil and Gas Production in Indiana in* 1938

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[a]	To End of 1938	During 1938
1	Trenton, "*Many*"	52	127,*xxx*	650,*xxx*	107,*xxx*,*xxx*	3*x*,*xxx*
2	Greensburg, *Decatur*	45	0	37,*xxx*	0	0
3	Loogootee, *Daniess-Martin*	38	3*xx*	1,9*xx*	0	0
4	West Princeton, *Gibson*	35	1,6*xx*	5*xx*	1,3*xx*,*xxx*	11,5*xx*
5	Riley, *Vigo*	32	640	0	1*xx*,*xxx*	4*xx*
6	Oakland City, *Pike*	31	3,1*xx*	2*xx*	*y*	28,880
7	Harrison Co., *Harrison*	28	0	6,6*xx*	0	0
8	Shelburn-Graysville, *Sullivan*	27	5,0*xx*	1,6*xx*	6,8*xx*,*xxx*	7*x*,*xxx*
9	Union-Bowman, *Pike-Gibson*	22	4,6*xx*	5*xx*	*y*	182,050
10	Oatesville-Wheeling, *Pike-Gibson*	19	1,9*xx*	0	*y*	165,*xxx*
11	Alford, *Pike*	19	240	960	3*xx*,*xxx*	3,960
12	Monroe City, *Knox*	16	4*xx*	0	*y*	1,890
13	Tri-County-Somerville, *Pike-Gibson*	13	350	80	142,*xxx*	15,120
14	Connelburg, *Daviess*	13	6*xx*	5*x*	*y*	4,080
15	Veale, *Daviess*	12	400	0	*y*	11,040
16	Siosi, *Vigo-Sullivan*	12	750	0	2,56*x*,*xxx*	24*x*,*xxx*
17	Troy-Tell City, *Spencer-Perry*	10	850	80	7*x*,*xxx*	13,*xxx*
18	Rock Hill-Grandview, *Spencer*	10	160	0	47,*xxx*	5,*xxx*
19	Harmon, *Pike*	10	20	6*xx*	0	)
20	Unionville, *Monroe*	9	0	1,4*xx*	0	0
21	Hudsonville, *Daviess*	9	0	1,0*xx*	0	0
22	Francisco, *Gibson*	9	760	140	8*x*,*xxx*	9,216
23	Bristow, *Perry*	9	180	120	57,*xxx*	4,*xxx*
24	Oaktown, *Knox*	8	40	1,000	52,*xxx*	7,2*xx*
25	Vanderburgh, *Vanderburgh*	7	580	0	328,*xxx*	40,*xxx*
26	Blairsville, *Posey-Vanderburgh*	4.7	350	0	141,*xxx*	38,*xxx*
27	Prairie Creek, *Vigo*	1.5	600	0	16*x*,*xxx*	150,*xxx*
28	Heusler, *Posey*	0.6	200	0	27,708	27,708
29	Total		151,*xxx*	701,*xxx*	12*x*,*xxx*,*xxx*	1,058,000

[a] Footnotes to column heads and explanation of symbols are given on page 240

estimated potential flow is from 800 to 1000 bbl. per day. The whole area will be actively developed during the next few months.

The Prairie Creek oil field, discovered in August 1937, in southwestern Vigo County, had 14 producing wells at the close of 1938, and no dry holes. Prairie Creek field is on a dome structure very similar to Siosi, which is about 3 miles to the southwest. Two wells were drilling in Prairie Creek at the end of 1938.

In wildcat drilling, Sullivan, Perry, and Daviess Counties led in the order named. During the closing months of the year, however, the scene

TABLE 1.—(*Continued*)

Line Number	Total Gas Production Millions Cu. Ft.		Number of Oil and/or Gas Wells					Oil-production Methods at End of 1938		Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1938
				During 1938		At End of 1938		Number of Wells			Average at End of		Gravity A.P.I. at 60° F.
	To End of 1938	During 1938	Completed to End of 1938	Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Pumping	Miscellaneous	Initial	1937	1938	Weighted Average
1	80x,xxx	2xx	26,5xx	19	y	2xx	5xx	2xx	1x	325	y	y	36
2	3,7xx	125.x	36x	5	17	0	21x	0		300	105	100	0
3	y	48.2	58	0	0	0	13	0		250	125	90	0
4	0	0	149	1	0	52	0	52		0	0	0	35
5	0	0	33	0	0	1	0	1		0	0	0	48
6	0	0	263	0	0	26	0	26		0	0	0	2x
7	3,3xx	211.5	113	1	0	0	35	0		{ 90, 175	y	40, 75, 170 }	0
8	1,xxx	32.3	1,093	12	14	344	15	1xx	2xx	110	y	35	35
9	y	17.x	398	6	7	226	3	226		y	y	y	33
10	0	0	253	0	5	197	0	197		0	0	0	32
11	y	74.7	92	1	2	7	21	7		y	75	45	38
12	0	0	15	0	0	7	0	7		0	0	0	y
13	y	y	74	0	3	12	y	12		y	y	y	34
14	y	0	56	3	3	13	0	16		0	0	0	y
15	0	0	73	0	0	27	0	27		0	0	0	y
16	0	0	83	2	0	62	0	62		0	0	0	46
17	355.x	82.3	69	7	y	27	9	27		200	175	150	37
18	0	0	16	0	y	6	0	6		0	0	0	38
19	y	20.x	28	0	0	0	7	0		450	35	27	0
20	0	0	17	0	0	0	0	0		250	y	y	0
21	y	79.4	51	2	1	0	16	0		275	175	y	0
22	1,230.7	54.7	35	0	2	13	7	13		690	y	y	26
23	0	0	44	1	y	2x	5	2x		0	0	0	33
24	1,594.6	298.9	78	8	y	10	4x	10		325	2xx	y	35
25	0	0	88	2	0	49	0	49		0	0	0	29
26	0	0	29	0	1	24	0	24		0	0	0	30
27	0	0	14	10	0	14	0	14		0	0	0	40
28	0	0	9	9	0	9	0	9		0	0	0	37
29	y	1,244.	30,xxx	89	y	1,346	9xx	1,1xx					

of the greatest activity was shifting rapidly to Knox, Gibson, Posey, Warrick, and Spencer Counties and it is probable that these counties will receive the major portion of wildcat tests during 1939. Development during part of 1938 was seriously handicapped by bad weather conditions, but leasing and geological and geophysical prospecting continued unabated.

Conditions in older fields during the year 1938 were about the same as those that prevailed in 1937. Water in the Harrison County field,

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1938	
	Name	Age[e]	Depth, Average in Feet		Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
			Bottoms of Productive Wells	To Top of Productive Zone						
1	Trenton	Ord	1,050–1,250	980–1,230	DL	Por	y	A	Pre-Cambrian	3,996
2	Trenton	Ord	907	886	DL	Por Fis	y	A	Pre-Cambrian	3,055
3	Chester sands	MisU	540	532	S	Por	15	A	St. Louis (Mis)	783
4	W. Princeton sand (Brazil)	PenL	920	890	S	Por	y	AF	St. Louis (Mis)	2,048
5	Corniferous	DevM	1,625	1,615	L	Por	y	A	Corniferous (Dev.)	1,709
6	Oakland City and Brown sands	MisU	1,107–1,126	1,085–1,112	S	Por	y	A	Paoli (MisU)	1,444
7	New Albany	DevU	680	650	H	Fis	85	M	Trenton (Ord)	1,770
8	Unnamed 1, 2, 3, 4, Cypress, Salem Niagara	PenL, MisU, MisM, SilM	325, 560, 667, 775, 810, 1,500, 2,285	298, 545, 640, 730, 800, 1,480, 2,270	S, S, L, L	Por	y	AM	Niagara (Dev. Sil)	2,870
9	Cypress, Mooretown Paoli	MisU	950–1,250	945–1,244	S	Por	y	A	Salem (MisM)	2,205
10	Sample, cypress Mooretown, Paoli	MisU	1,270, 1,290, 1,360, 1,740	1,250, 1,270, 1,340, 1,725	S	Por	y	A	Handsburg (MisM)	2,050
11	Oakland City and Brown sands	MisU	640, 1,100, 1,140	630, 1,080, 1,130	S	Por	x	A	St. Louis (MisM)	1,413
12	Mansfield, cypress Mooretown & Paoli	PenL (1) MisU (2, 3, 4)	1,240, 1,560	1,225, 1,475, 1,535	S, L	Por	y	M	St. Genevieve (MisM)	1,565
13	Brazil, Oakland City	PenL MisU	331–1,335	315–1,317	S	Fis Por	y	A	McClosky (MisM)	1,998
14	Lower Chester	MisU	640	630	S	Por	y	A	Chester (MisU)	895
15	Veale sand	MisU	1,169	1,161	S	Por	y	A	Devonian (?)	2,618
16	Corniferous, Niagara	DevM SilM	2,115	2,100	L	Por	y	D	Trenton (Ord)	3,554
17	Sample, cypress Mooretown	MisU	492, 728, 759, 827, 1,193	486, 714, 747, 805, 1,168	S	Por	y	N MF	"Mis Lime"	1,708
18	Bethel (sample)	MisU	1,320	1,310	S	Por	y	MC	"Mis Lime"	1,500
19	Oakland city (Mooretown)	MisU	1,125	1,110	S	Por	y	A	St. Genevieve (MisM)	1,021
20	Corniferous	DevM	850	800	D	Por	40	AF	Trenton	2,102
21	Barker sand	MisU	330–660	320–650	S	Por	10	T	McClosky (MisM)	1,375
22	Brown sand (Paoli)	MisU	1,450	1,430	S	20	25	A	Ordovician	4,006
23	Tar springs, cypress Elwren	MisU	350	330	S	Por	20	ML	"Mis Lime"	710
24	Staunton (unnamed)	PenL	610–802	580–790	S	Por	y	ML	Chester (MisU)	1,593
25	Mansfield	PenL	911	899	S	Por	y	ML	Glen Dean (MisU)	1,795
26	Mansfield	PenL	1,031	1,007	S	25	30	ML	Chester (MisU)	1,920
27	Corniferous, Niagara	DevM SilM	2,165	2,074	L	Por	y	D	Niagara (SilM)	2,190
28	Waltersburg (U. Chester)	MisU	1,800	1,750	S	Por	y	AF	Chester (MisU)	1,823
29										

TABLE 2.—*Summary of Drilling Operations in Indiana in 1938*

Important Wildcats Drilled in 1938

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production per Day		Remarks
		Sec.	Twp.	Rge.					Oil, U. S., Bbl.	Gas, Millions Cu. Ft.	
1	Clay	19	12 N	5 W	1,500	Pen	Dev	W. A. Sage			Dry hole
2	Gibson	13	3 S	14 W	2,920	Pen	McClosky (MisU)	W. O. Allen et al.	1,000±		Oil well
3	Greene	19	7 N	7 W	976	Pen	MisM	A. S. Reed			Dry hole
4	Knox	7	5 N	9 W	803	Pen	PenL	L. E. Jordan & Son		.405	Eastern Extension to Oaktown Field. Tubing pressure, 290 lb. per sq. in.
5	Knox	4	5 N	7 W	2,375	Pen	Dev	Worthington Petr. Co.			Dry hole
6	Parke	29	17 N	7 W	1,074	Mis L	Dev	Dan Williams Beckwith			Dry hole
7	Perry	18	6 S	3 W	928	Pen	Chester (MisU)	Frank Damron			Dry hole
8	Pike	26	1 N	7 W	1,375	Pen	MisM	Claude L. Trusler			Dry hole
9	Posey	1	7 S	12 W	1,749	Pen	Chester (MisU)	Sun Oil Co.	29		Discovery well, Heusler field
10	Posey	15	4 S	12 W	1,985	Pen	Chester (MisU)	George W. Miller			Dry hole
11	Posey	29	8 S	14 W	2,709	Pen	McClosky (MisU)	Sun Oil Co.	30		Discovery well, Point field. Later abandoned
12	Posey	4	7 S	14 W	5,035	Pen	Dev	Carter Oil Co.			Show oil 1050–1064. Deepest hole in state to date
13	Randolph	5	21 N	15 E	1,100+	Sil	Trenton	Sim. B. Hood, Trustee			Dry hole. Show oil in Trenton
14	Shelby	30	12 N	8 E	841	Dev	Trenton	R. E. Haymond			Tubing pressure, 115 lb. per sq. in. Gas well. I. P. unknown
15	Sullivan	2	7 N	10 W	2,753	Pen	Dev	A. S. Reed			Show oil 776–791; oil and gas 2,694–2,719. Dry hole
16	Sullivan	11	8 N	10 W	2,661	Pen	Dev	C. T. Coats & A. R. McClennon			Dry hole; show gas 870; 1,015.
17	Sullivan	36	8 N	9 W	4,160	Pen	St. Peter (OrdL)	Felmont Corp.			Dry hole. Gas (100 M) 450–470; gas show 2,351 ft.
18	Sullivan	13	8 N	11 W	2,870	Pen	Dev	Carter Oil Co.			Dry hole; oil odor 2,100–2,110.
19	Sullivan	7	8 N	8 W	2,262	Pen	Dev	Joe Burnstein			Dry hole. Show gas 195; oil and gas 545–560; gas 593, show oil 2,118–2,172
20	Sullivan	35	8 N	10 W	821	Pen	Pen	A. S. Reed		2.00	
21	Sullivan	20	9 W	10 W	2,556	Pen	Niagara	Carter Oil Co.			Dry hole
22	Vanderb rgh	2	5 S	10 W	2,348	Pen	McClosky (MisM)	Sun Oil Co.			Dry hole
23	Vanderburgh	31	5 S	11 W	1,300	Pen	Chester (MisU)	Vanderburgh Oil Corp.			Dry hole
24	Warrick	16	7 S	8 W	1,914	Pen	McClosky (MisM)	LeMoine & Taylor			Dry hole
	Total								1,059	2.405	

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1938	21	19
Number of oil wells completed during 1938	45	3
Number of gas wells completed during 1938	38	3
Number of dry holes completed during 1938	34	36

encroaching from the south, was still causing trouble. Weaker wells in this field are being shut in during the low-drain months to enable them to recuperate. Operators believe this will prolong their life. The old Trenton area had several completions for small oil and gas wells.

In the spring and summer of 1939 many wells should be drilled in the new fields discovered during the past year, as well as many wildcat tests. Approximately four million acres have been leased in Indiana during the past two years, including many large blocks that appeared favorable from geological or geophysical prospecting. Several deep tests are in progress, chiefly to the McClosky, Devonian, Trenton, and St. Peter, and many more are due to start within the next few months.

Kansas Oil and Gas during 1938

By W. A. Ver Wiebe*

(New York Meeting, February, 1939)

The year 1938, with a production of 58,784,250 bbl. from 18,790 wells shows a slight recession from the high peak of oil production reached the previous year, when slightly over 68 million barrels of oil was marketed. The previous high peak had been reached in 1917 with a total of 45,451,000 bbl. Another still earlier peak was reached in 1904, during which year slightly less than 5 million barrels was produced and sold. The production of gas, on the other hand, probably reached a new peak during 1938 with a total of over 60 billion cubic feet. This peak, however, was not the highest peak, for during the year 1908 over 80 billion cubic feet was produced. Between these two high peaks the production dropped down to 16 billion cubic feet in the year 1921.

The number of wells drilled during the year totals 1569. This figure is somewhat lower than the figure given in several trade journals because it does not include wells that were deepened or recompleted in a different geological horizon. Nearly three-fourths (or 1107) of the total number of wells were completed as commercial oil wells (915 in western and 192 wells in eastern Kansas). The commercial gas wells completed number 50, of which 4 are in eastern Kansas and 46 in western Kansas. The remaining 412 completions include 130 dry holes in eastern and 282 dry holes in western Kansas. Based on daily potential capacity, the new discoveries of the year accounted for 70,000 bbl. of new oil for eastern and 1,220,000 bbl. of new oil for western Kansas.

It is interesting to note in this connection that the number of wells completed in the state rose gradually to a first peak in 1904, when 2782 were drilled. The number dropped off rapidly to 368 three years later, but rose to the second and highest peak in 1918 when 4671 wells were completed. In the period between 1904 and 1912 more gas wells than oil wells were completed. Between the high peak of 1918 and the somewhat lower peak in 1937, the low point was reached during 1931, with the completion of only 470 wells.

In the matter of new pools discovered, Kansas again ranks high. The exact number depends somewhat upon the interpretation of a new area whether it should be called a new pool or a long extension of an

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older pool. In some cases this determination cannot be made until more wells are drilled within the area. Therefore, the figures given in this report may differ from those presented in the trade journals. Table 3 of this report lists 49 new oil pools and 2 new gas pools. Trade journals are also inclined to list as new pools the areas in which oil is discovered in new producing horizons in old pools. During 1938 discoveries of this type were made in 16 areas. Of this total 13 new oil discoveries were made in new horizons present in old pools, while the other three were new horizons discovered in pools previously found during the year 1938.

New Geological Information.—In most cases these new horizons are the same as those found productive elsewhere in the state. It is common, for example, to find the Arbuckle productive in a pool having production from the Lansing-Kansas City (formerly called Oswald), or vice versa. Less often the new horizon is the Simpson (sometimes called the Wilcox) or a higher formation in the Pennsylvanian system. During 1938 three entirely new and unexpected producing horizons were found at widely separated points. The most remarkable of these is the pre-Cambrian granite, which was found to contain commercial quantities of oil in the Hall pool as well as the Gurney pool, both of which are in Russell County. In this connection it will be recalled that attention was directed to the presence of oil in pre-Cambrian quartzite in the A.I.M.E. report for 1936.* This occurrence is in the Orth pool, Rice County. Although the occurrence of oil in granite is mentioned here for the first time, it appears from a study of well logs that the actual commercial production began in 1937 when the Empire Oil and Gas Co. completed its No. 1 Ebel well in the Gurney pool in sec. 24, T. 14 S., R. 14 W. Somewhat later, the No. 2 Rein well drilled by the Stanolind Oil Co. also derived some of its oil from the pre-Cambrian. However, it remained for the No. 3 Opdyke well of the Skelly Oil Co. (Hall pool) to establish the fact that actual production was coming from granite and not from the erosional rubble sometimes found above the granite, and then referred to as the "Granite Wash." This well drilled into granite from 3141 to 3243 ft., or a total of over 100 ft. Commercial quantities of oil were found in a pay zone that includes the interval between 3156 and 3181 ft. It is perhaps needless to point out that this occurrence of oil will tend to change some of the older ideas about the origin of oil.

Another rather unexpected new horizon is the Tonganoxie sand found in the No. 1 Shepherd well drilled by Bunte Brothers et al. in Kingman County (10-27-10). Apparently this sand occurs at the same horizon as the rather prolific Stalnaker sand in central Kansas, and is one of the sand lenses in the Stranger formation. Fig. 1 shows the position of this sand as well as the position of the pre-Cambrian horizon.

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* *Trans.* A.I.M.E. (1937) **123**, 341, 354.

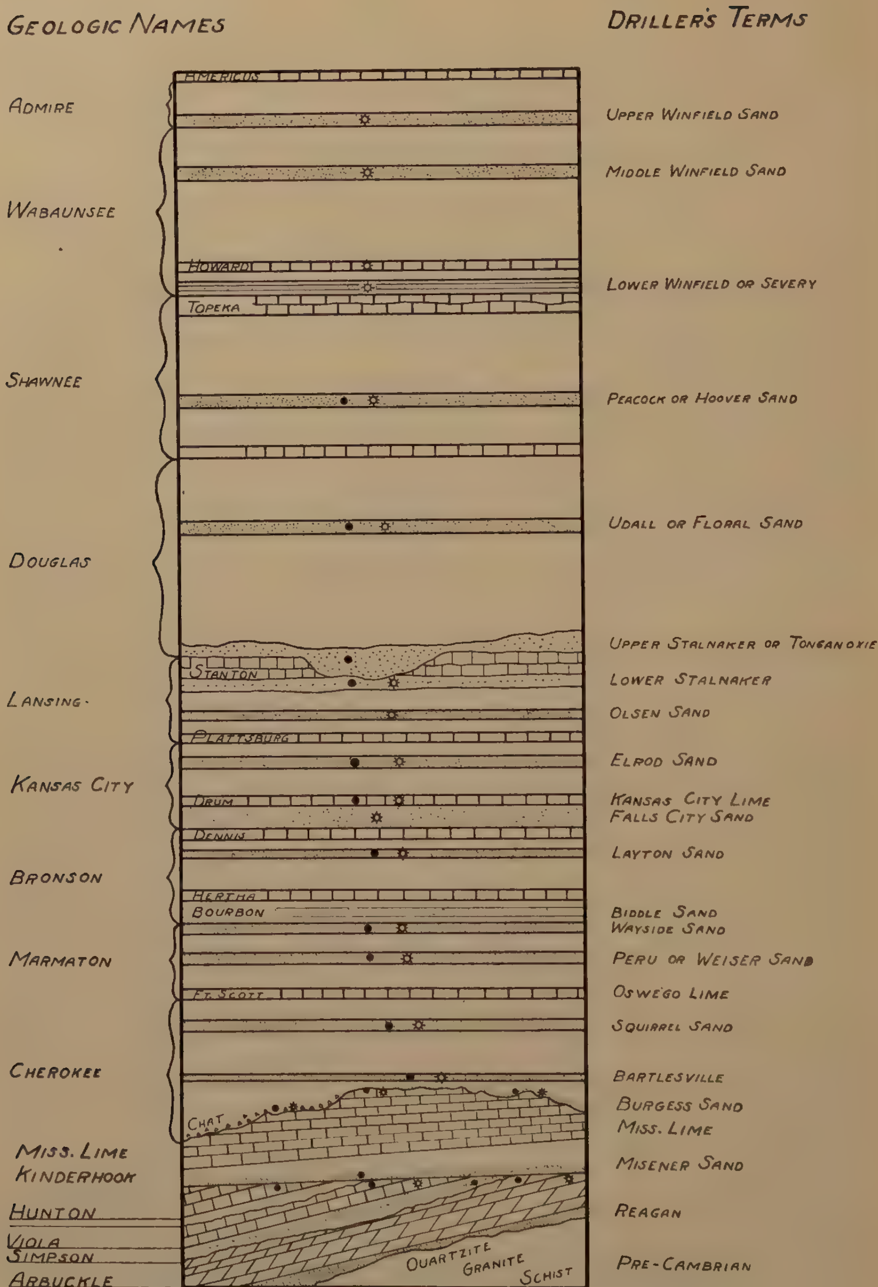

FIG 1.—PRODUCING HORIZONS OF SOUTHERN KANSAS.
Drawn by Edgar Rehn from data supplied by the author.

The third new horizon for oil production is the Oread limestone, which occurs at the base of the Shawnee group of the Pennsylvanian system. This limestone appears to contain oil in at least one well in the Michel pool of Russell County. The discovery well was completed during August. Although not as remarkable as the foregoing discoveries, it is nevertheless interesting to record the first occurrence of commercial oil in the Simpson formation of Ellis County (Blue Hill pool).

Water Disposal and Repressuring.—The number of wells drilled for the purpose of disposing of salt water increased greatly during the year. At the beginning of 1938 there were approximately 175 such wells in 58 pools. About one-fourth of the wells were using the basal sands in the Cretaceous system (Dakota and Cheyenne) for disposal, while one-fifth were using the salt zone in the Wellington formation of Permian age. By far the largest number were using the Arbuckle or the Arbuckle in conjunction with the underlying Reagan and pre-Cambrian for water disposal. A few wells found porous zones in the Big Blue succession, one well was using the Lansing and three wells were using the Viola or Simpson formations of the Ordovician. Pressures used range all the way from gravity to 500 lb. The water-taking capacity ranged from small amounts to 1200 bbl. per hour, with a common capacity of about 400 bbl. The average input per day ranged from small amounts to the surprising total of 15,257 (Oxford pool of Sumner County). Most of these wells were less than two years old, yet a few have taken enormous amounts of water. For instance, one well in the Greenwich pool of Sedgwick County has taken over 3½ million barrels of salt water while another in the Oxford pool has taken over 3¾ million barrels. It is also significant to note that one pool, the Oxford pool, has absorbed over 8 million barrels of salt water, nearly all of which was deposited in the Arbuckle formation by gravity. The Greenwich pool stands in second place in this regard, having allowed the disposal of nearly 5 million barrels (also to the Arbuckle by gravity).

Repressuring operations in Kansas began some years ago but extensive operations on a large scale date from late 1935 and early 1936. At the beginning of 1938 there were at least 325 wells used for the purpose of taking in water to repressure the producing sand. Most of the water used came from the surface, although in many places water extracted from the same sand that was being repressured was used. This water was first treated chemically or by filtration, aeration or simply by settling. The pressure used in these operations varies from gravity to 625 lb., with a common average around 200 to 400 lb. The maximum capacity of the wells measured on the basis of so many barrels per hour is from less than 1 bbl. to 10 bbl. The daily input of water varies from small amounts to slightly over 100 bbl. In exceptional cases, however, as much as 1200 to 1400 bbl. was being put into the sand (Viola of the

TABLE 1.—*Producing Oil Fields in Kansas in 1938*

Field and Location	Discovery Date	Area, Acres	Production: In 1938	Production: Cumulative	Number of Wells Producing	Producing Horizon: Name	To Top, Ft.	Thickness, Ft.	Character
Barber County			92,169	209,981	11				
Lake City, 7-31-13W	July 1937	160	9,158	17,450	1	Viola	4,435	5	Lime
					1	Arbuckle	4,607	4	Dolomite
Medicine Lodge, 13-33-13W	Mar. 1937	40	8,701	15,409	1	Viola	4,845	2	Lime
Whelan, 32-31-11W	Aug. 1934	640	74,310	177,122	8	Chat	4,355	29	Insoluble Residue
Barton County			7,325,593	24,589,573	793				
Ainsworth,[1] 26-16-13W	Dec. 1936	4,200	507,779	729,414	49	Arbuckle	3,390	5	Dolomite
Albert, 30-18-15W	Jan. 1935	1,200	108,667	233,824	10	Reagan	3,601	15	Sandstone
Beaver, 16-16-12W	Dec. 1934	1,000	139,946	528,315	19	Arbuckle	3,348	3	Dolomite
						Reagan	3,335	6	Sandstone
Beaver North, 4-16-12W	Oct. 1937	160	30,909	33,307	3	Arbuckle	3,316	10	Dolomite
Bloomer, 36-17-11W	Feb. 1936	2,000	886,751	2,656,471	4	Lans. K. C.	3,044	10	Lime
					86	Arbuckle	3,257	24	Dolomite
Boyd, 3-18-14W	Dec. 1938	40			1	Arbuckle	3,365	2	Dolomite
Clawson, 17-20-11W	Dec. 1938	40			1	Arbuckle	3,285	14	Dolomite
Davidson, 4-16-11W	Mar. 1928	80	10,993	28,430	1	Arbuckle	3,314	26	Dolomite
					1	P. B. C.	3,317	21	Conglomerate
Eberhardt, 14-19-11W	June 1935	160	24,365	109,501	4	Arbuckle	3,311	49	Dolomite
Ellinwood, 9-20-11W	July 1932	1,200	127,757	1,327,379	15	Arbuckle	3,304	30	Dolomite
Ellingwood North, 33-19-11W	July 1937	80	14,067	22,154	2	Arbuckle	3,328	22	Dolomite
Ellingwood West, 7-20-11W	Apr. 1938	160	18,469	18,469	3	Arbuckle	3,346	6	Dolomite
Feist, 29-18-11W	Mar. 1936	40	6,962	36,321	1	Arbuckle	3,430	3	Dolomite
Hagan, 20-20-11W	Dec. 1938		1,059	1,059	1	Arbuckle	3,323	7	Dolomite
Heiser, 16-19-14W	Aug. 1935	40	4,872	12,330	1	Lans. K. C.	3,228	25	Lime
Hiss, 31-20-13W	Feb. 1936	160	39,810	178,968	4	Lans. K. C.	3,270	20	Lime
Hoisington, 21-17-13W	Jan. 1938	160	14,985	14,985	1	Lans. K. C.	3,440	12	Lime
					1	Arbuckle			Dolomite
Kraft, 10-17-11W	Mar. 1937	1,800	278,872	354,358	30	Arbuckle	3,281	8	Dolomite
						Arbuckle	3,231	5	Dolomite
Lanterman, 15-19-11W	Jan. 1935	200	57,786	122,297	4	Lans. K. C.	3,109	6	Lime
					2	Arbuckle	3,235	3	Dolomite
Odin, 10-17-12W	May 1938	80	8,646	8,646	2	Arbuckle	3,340	2	Dolomite
Prusa, 20-16-11W	Dec. 1938		none	none	1	Arbuckle	3,335	17	Dolomite
Rick, 1-19-11W	Aug. 1936	160	38,396	135,825	5	Arbuckle	3,355	2	Dolomite
Silica, 12-20-11W	Oct. 1931	8,400	4,244,984	16,359,080	455	Arbuckle	3,309	19	Dolomite
Silica South, 24-20-11W	Oct. 1935	4,800	757,112	1,675,034	83	Arbuckle	3,274	10	Dolomite
Straub[2]									
Susank[3]									
Wolf, 36-19-12W	Aug. 1938	40	2,406	2,406	1	Arbuckle	3,346	28	Dolomite
Butler County			5,569,860						
Augusta North, 28-27-4E	Jan. 1914	1,280	154,829	13,054,732	68	Kans. City	1,900	35	Limestone
						Layton	2,000		Sandstone
						Wilcox	2,380	10	Sandstone
						Arbuckle	2,410	5	Dolomite
Augusta South 21-28-4E	Jan. 1916	9,000	350,217	32,936,433	156	Kans. City			Lime
						Ft. Scott			Lime
						Wilcox	2,445	10	Sandstone
						Arbuckle	2,600	5	Dolomite
Bausinger, 24-27-3E	July, 1929	200	12,286		5	Wilcox	3,050	29	Sandstone
Benton, 10-26-3E	Jan. 1925	80	5,475		2	Chat	2,765	5	Insoluble Residue
Blankenship, 2-26-8E	Jan. 1921	1,200	86,870	4,092,827	91	Bartlesville	2,650	50	Sandstone
Brandt, 15-28-7E	June 1936	400	70,470	79,337	9	Chat	2,692	8	Insoluble Residue
DeMoss, 5-28-7E	Oct. 1924	160	27,083	41,467	4	Burgess	2,732	10	
Douglass, 2-29-4E	Jan. 1916	2,400	27,047		21	Lans. K. C.	1,790	40	Lime
						Varner	2,835	50	
Elbing, 8-23-4E	Aug. 1918	1,800	489,465	17,952,957	88	Lans. K. C.	2,330	70	Lime
						Viola	2,430	40	Lime
El Dorado, 29-25-5E	Sept. 1915	25,000	3,018,428	171,917,319	1,733	Admire	600	10	Sandstone
						Lans. K. C.	1,700	20	Lime
						Viola	2,500	5	Lime
						Simpson	2,510	15	Sandstone
						Arbuckle	2,550	5	Dolomite

[1] Ainsworth South is combined with Ainsworth.
[2] Abandoned 1938.
[3] Included with Trapp. See Russell County.

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production		Number of Wells Producing	Producing Horizon			
			In 1938	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Fox Bush, 25-28-5E	Jan. 1917	5,000	158.374	15,324,704	172	Bartlesville	2,730	40	Sandstone
Garden, 6-27-6E	Mar. 1928	1,600	72,745		30	Bartlesville	2,760	10	Sandstone
Gelwich, 6-27-4E	Apr. 1930	80	12,319		2	Viola	2,924	2	Lime
Haverhill, (15-34)-27-5E	Apr. 1927	700	97,638	2,954,403	61	Bartlesville	2,700	50	Sandstone
Keighley, (14-33)-27-7E	Jan. 1925	1,800	92,163		52	Bartlesville	2,650	50	Sandstone
King, 17-24-4E	Jan. 1937	80	124	2,123	2	Kans. City	2,145	20	Lime
Kramer, 4-28-6E	Jan. 1926	500	63,693		22	Viola Wilcox Arbuckle	3,050 3,020 3,040	3 15 5	Lime Sandstone Dolomite
Leon, 19-27-6E	Oct. 1926	500	38,581		22	Chat Viola	2,660 3,050	50	Insol. Res. Lime
McCullough, 1-28-6E	Feb. 1926	400	131,980	235,235	9	Wilcox	3,169	6	Sandstone
McCaig, 13-28-6E	Mar. 1937	80	7,045	13,145	2	Bartlesville	2,720	20	Sandstone
Madden, 27-23-4E	May 1937		2,040	2,110	1	Lans. K. C.	2,065	47	Lime
Moore, 12-25-3E		120	8,760		3	Mis. Lime	2,667	9	Lime
Pettit, 21-28-6E	July 1936	40	No runs		1	Wilcox Mis. Lime	3,160 2,826	3 4	Sandstone Lime
Potwin, 36-24-3E	Jan. 1921	3,200	341,604		80	Kansas City Mis. Lime	2,250 2,660	5 5	Lime Lime
Reynolds-Shaffer, 4-27-6E	June 1926	900	115,861		3 20	Mis. Lime Viola	2,760 3,125	10 25	Lime Lime
Seward, 14-27-7E		600			16	Bartlesville	2,650	50	Sandstone
Smock-Sluss, 19-26-6E	Mar. 1918	1,500	63,802		43	Bartlesville Viola	2,685 3,000	30	Sandstone Lime
Snowden-McSweeney, 2-29-6E	1930	160	3,679		1	Mis. Lime	2,833		Lime
Starkey, 16-30-4E	Oct. 1937	abandoned				Bartlesville	2,784	18	Sandstone
Steinhoff, 21-29-6E	Jan. 1926	160	6,811		3	Chat	2,803	5	Insol. Res.
Stern, 27-27-6E	Jan. 1928	600	72,380		11	Chat Viola	2,752 3,050	8	Insol. Res. Lime
Weaver, 1-28-5E	Jan. 1929	400	5,168		9	Bartlesville	2,690		Sandstone
Young, 27-26-7E	1919	600	32,923		20 1	Kans. City Chat	2,190 2,650	5 50	Lime Insol. Res.
Chautauqua County									
Fisher, 10-34-9E	Dec. 1937				1	Altamont	1,648	31	Lime
Foster, 6-33-12E	July 1937	40				Mis. Lime	2,200	30	Lime
Kingston, 17-32-10E	Jan. 1937	40			1	Lans. K. C.	1,437	2	Lime
Clark County									
Morrison, 17-32-21W	Oct. 1936	160	35,864	67,090	2	Viola	6,467	4	Lime
Coffey County			30,353						
Van Noy (1-14)-23-14E (6-18)-23-15E					36	Peru Chat	1,138 1,622	12 6	Sandstone Insol. Res.
Cowley County			3,200,286						
Baird, 16-34-3E		160	6,144		4	Bartlesville	3,260		Sandstone
Biddle, 12-32-4E 7-32-5E		600	48,636		22	Stalnaker Kansas City	2,300 2,600		Sandstone Lime
Burden, 22-31-6E	Jan. 1926	1,200	93,112		36	Bartlesville	2,865	35	Sandstone
Carson, 19-32-3E	Oct. 1924	400	228,000	2,932,823	18	Layton Arbuckle	2,600 3,450		Sandstone Dolomite
Clarke, 6-31-4E	Jan. 1914	180	17,931	800,534	4	Bartlesville	2,840		Sandstone
Countryman, 4-33-7E, 33-32-7		600	12,228		8	Layton	1,950		Sandstone
David, 35-30-4E, 2-31-4	July 1935	500	59,917	230,226	12	Bartlesville	2,935	40	Sandstone
David South, 11-31-4E, 2-31-4	Jan. 1934	200	21,264	70,534	5	Bartlesville	3,010	19	Sandstone
Dexter, 24-33-6E	Jan. 1903	1,200	4,105		1	Mis. Lime	2,750		Lime
Dunbar, 29-30-5E	Sept. 1938		2,882	2,882	1	Kansas City	2,229	36	Lime
Eastman, 31-30-6E	Jan. 1924	1,200	68,711	2,235,834	33	Bartlesville	2,770	100	Sandstone
Elrod, 4-32-5E	June 1918	160		127,088	3	Elrod sand	2,390	10	Sandstone
Falls City, 17-35-7E	Jan. 1916	600	348,106	1,137,336	13	Stalnaker	2,000		Sandstone
Ferguson West, 21-30-8E		100	8,121		3				
Frog Hollow, 20-32-5E	Jan. 1937	300	44,861	78,296	8	Bartlesville	3,089	8	Sandstone
Frog Hollow East, 21-32-5E	Aug. 1938				1	Bartlesville	3,042	12	Sandstone

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production: In 1938	Production: Cumulative	Number of Wells Producing	Producing Horizon: Name	Producing Horizon: To Top, Ft.	Producing Horizon: Thickness, Ft.	Producing Horizon: Character
Geuda Springs, 8-34-3E	May 1936	600	54,958	125,430	10	Chat	3,320		Insol. Res.
Graham, 9-33-3E	June 1924	800	29,127	2,413,042	15	Layton Arbuckle	2,550 3,500		Sandstone Dolomite
Grand Summit, 10-31-8E		600	36,044		13				
Hittle, 21-31-4E	Jan. 1926	600	145,511		17 2	Stalnaker Arbuckle	2,400 3,280	 8	Sandstone Dolomite
Mahannah, 6-30-8E	1918	160	9,817		2	Burgess	2,730		
McCormick, 13-31-7E	Aug. 1922	40		196,354	1				
Murphy, 8-35-3E	Jan. 1933	600	47,161		9	Chat	3,300		Insol. Res.
Olsen, 1-35-7E	Apr. 1921	300	7,785		7	Ft. Scott	2,400		Lime
Rainbow Bend, 20-33-3E	Dec. 1923	2,000	385,241	12,255,296	113	Burgess	3,200	50	Sandstone
Reidy, 31-31-8E		160	2,555		3				
Rock, 15-30-4E	Jan. 1923	500	153,903	1,353,738	24	Bartlesville	2,760	45	Sandstone
Rock West, 16-30-4E	Oct. 1937	160	75,935	81,399	4	Bartlesville	2,784	18	Sandstone
Rock North, 3-30-4E	Sept. 1937	200	6,240	9,803	5	Bartlesville	2,807	21	Sandstone
Sherwood, 11-31-4E	May 1936	160	31,030	42,455	4	Bartlesville	3,010	19	Sandstone
Smith, 10-31-3E	Jan. 1917	600	13,870		12	Bartlesville	3,050	20	Sandstone
State, 15-32-4E	Jan. 1926	1,500	100,130		39	Layton Arbuckle	2,300 3,500		Sandstone Dolomite
Trees, 19-30-4E	Jan. 1934	300	70,578		9	Bartlesville	2,950	25	Sandstone
Turner, 30-32-6E	June 1937	240	53,224	74,538	6	Layton	2,232	15	Sandstone
Udall, 28-30-3E			2,342	43,276	1				
Weathered, 28-31-3E	July 1935	1,000	876,006	1,222,625	2 2 25	Lans. K. C. Mis. Lime Arbuckle	2,455 3,065 3,400		Lims Lime Dolomite
Wilson, 9-33S-6E	Nov. 1938		2,258	2,258	1	Arbuckle	3,519	4	
Winfield, 36-32-4E	Nov. 1914	5,000	132,553		65	Peacock Layton Bartlesville Arbuckle	1,400 2,300 3,050 3,300		 Sandstone Sandstone Dolomite
Edwards County									
McCarty, 31-25-17W	May 1929	40	Temporarily shut in		1	Basal Cong.	4,545	10	Conglomerate
Elk County			280,320						
Moline, 3-31-10E	Dec. 1927	600			42	Encill Mis. Lime	1,150 1,980		Sandstone Lime
Sellars, 11-31-9E		40			1	Mis. Lime	2,300	22	Lime
Webb, 28-31-10E	Oct. 1924	3,600				Encill Red Ft. Scott Arbuckle	1,100 1,350 1,650 2,286		Sandstone Sandstone Lime Dolomite
Ellis County			3,107,134	7,536,397	363				
Antonino abandoned 1938									
Bemis, 16-11-17W	Oct. 1935 Apr. 1936	3,200	2,011,961	3,899,351	218	Topeka Arbuckle	3,032 3,380	8 2	Lime Dolomite
Bemis South, 2-12-17W	Dec. 1938	40			1	Arbuckle	3,592	11	Dolomite
Blue Hill, 14-12-16W	Aug. 1937	640	30,545	38,409	1 2 1	Arbuckle Lans. K. C. Wilcox	3,360 3,072 3,358	25 33 15	Dolomite Lime Sandstone
Burnett, 1-11-18W	Sept. 1937	80	28,111	28,111	2	Arbuckle	3,570	4	Dolomite
Burnett South, 12-11-18W	May 1938	600			8	Arbuckle	3,330	3	Dolomite
Catherine, 3-13-17W	June 1936	160	25,691	74,407	3	Lans. K. C.	3,362	12	Lime
Cress, 13-11-17	Mar. 1937	600	254,397	385,206	25	Arbuckle	3,293	9	Dolomite
Emmeram, 4-13-16	June 1937	40	10,238	20,921	1	Lans. K. C.	3,260	7	Lime
Hadley, 20-11-17W	Aug. 1927	40	3,252	51,654	1	Lans. K. C.	3,428	12	Lime
Haller, 10-11-18W	July 1936	40	2,305	10,327	1	Topeka	3,036	9	Lime
Koblitz, 23-12-18	Feb. 1937	100	250	1,993	2	Arbuckle	3,694	4	Dolomite
Kraus, 22-14-9	July 1936	100	11,934	37,241	2	Conglomerate	3,735	5	Conglomerate
Madden, 26-15-18	June 1936 Oct. 1936	160	10,319	36,515	1 1	Lans. K. C. Arbuckle	3,331 3,589	10 6	Lime Dolomite
Marshall, 36-11-18	Nov. 1936	1,000	129,548	253,229	14	Arbuckle	3,638	12	Dolomite
Peavey, 24-11-18	Nov. 1938				1	Arbuckle	3,425	9	Dolomite
Penny Wahn, 13-15-20	Sept. 1936	40	7,567	12,513	1	Conglomerate	3,653	5	Conglomerate
Richards, 5-11-18	Jan. 1938	120	8,621	8,621	3	Lans. K. C.	3,332	41	Lime
Ruder, 17-15-18	Aug. 1935	700	98,131	482,593	15	Lans. K. C. Arbuckle	3,422 3,572	18 10	Lime Dolomite

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production		Number of Wells Producing	Producing Horizon			
			In 1938	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Shutts, 5-12-17	Oct. 1928	2,000	196,527	1,632,697	22	Lans. K. C. Arbuckle	3,280 3,569	4 6	Lime Dolomite
Solomon, 28-11-19	June 1936	160	1,860	26,121	3	Arbuckle	3,629	3	Dolomite
Toulon, 3-14-17	Dec. 1935	200	30,855	80,026	5	Lans. K. C. Arbuckle	3,298 3,512	5 48	Lime Dolomite
Ubert, 12-13-18	Nov. 1936	160	28,093	46,043	4	Arbuckle	3,707		Dolomite
Victoria, 18-14-16	Sept. 1937	abandoned			1	Lans. K. C.	3,422	42	Lime
Walter, 2-12-18	May 1936	1,000	216,929	410,419	1 23	Topeka Arbuckle	3,160 3,619	5	Lime Dolomite
Yocemento[4]									
Ellsworth County			1,195,544	11,947,313	157				
Breford, 7-17-10	Sept. 1932	700	137,348	798,812	11 6	Lans. K. C. Arbuckle	3,140 3,368	12 27	Lime Dolomite
Habiger[5]									
Heiken, 25-17-10	Oct. 1930	320	20,483	306,196	4	Arbuckle	3,269	2	Dolomite
Lorraine, 13-17-9	Nov. 1934	5,500	815,500	6,687,569	2 87	Lans. K. C. Arbuckle	3,060 3,200	140 5	Lime Dolomite
Schroeder, 29-17-9W	Jan. 1938	600	47,985	47,985	9	Arbuckle	3,205	10	Dolomite
Stoltenberg, 21-16-10	June 1931	700	60,959	2,119,139	18	Arbuckle	3,333	14	Dolomite
Stratman, 1-17-10	Mar. 1931	600	96,226	1,844,905	16	Arbuckle	3,255	16	Dolomite
Wilkins, 13-17-10	Apr. 1934	120	17,043	142,707	4	Arbuckle	3,260	20	Dolomite
Finney County									
Nunn, 27-21-34W	June 1938	40	17,885	17,885	1	Mis. Lime	4,654	10	Lime
Graham County									
Morel, 15-9-21W	Apr. 1938	40			1	Arbuckle	3,718	2	Dolomite
Greenwood County			3,503,749						
Atyeo-Pixlee 6-22-10E	Jan. 1923	1,000	94,462		96	Bartlesville	2,000	50	Sandstone
Blackwell, 16-24-13E	Jan. 1923	1,000	3,619		5	Mis. Lime	2,327		Lime
Bradfield, 25-21-10E		600			14	Mis. Lime	2,300		Lime
Brinegar, 33-26-13E		500	7,483		31				
Browning, 8-22-10E	Jan. 1924	3,800	177,328		95	Bartlesville	2,314	76	Sandstone
Burkett, 13-23-10E	Jan. 1924	2,700	78,293		102	Bartlesville	2,000	100	Sandstone
Christy, 36-24-12E		2,000	5,413		11	Bartlesville	1,500	75	Sandstone
Climax, 7-27-11E	Jan. 1926	160	12,045		3	Mis. Lime	1,900		Lime
DeMalorie-Souder 19-21-10E	Jan. 1924	4,500	188,095		128	Bartlesville	2,150		Sandstone
Dunaway, 4-22-13E		1,000	87,710		60	Mis. Lime	1,800		Lime
Eureka, 35-25-10E	Jan. 1920	1,200	24,940		15	Mis. Lime	2,000		Lime
Fankhouser, 32-21-12E	Jan. 1926	2,500	49,943		66	Bartlesville	1,750	50	Sandstone
Gaffney, 6-24-11E	Aug. 1926	500		213,574	3				
Hamilton, 26-23-11E	Jan. 1929	3,000	132,313		95	Bartlesville	1,765	72	Sandstone
Henley, 25-25-9E	Nov. 1937	40			1	Mis. Lime	2,140	25	Lime
Hinchman, 17-24-13E		200	24,331		13	Mis. Lime	1,600	50	Lime
Lamont, 5-22-12E	Jan. 1927	2,600	137,846		108	Bartlesville	1,650		Sandstone
Madison, 1-22-11E	Jan. 1921	3,000	226,540	5,775,000	102	Bartlesville	1,800		Sandstone
Pedroja, 6-26-10E	Joined to Reece	40		5,508	1	Mis. Lime	2,154	7	Lime
Polhamus, 27-24-9E	Jan. 1922	1,400	33,365		45	Bartlesville	2,170		Sandstone
Quincy, 18-25-14	Jan. 1926	3,600	380,038		113	Bartlesville	1,420		Sandstone
Reece, 21-26-9E		1,200	58,586		21	Mis. Lime	2,100		Lime
Sallyards, 17-25-9E	Jan. 1921	8,000	162,425		132	Bartlesville	2,350	150	Sandstone
Scott, 19-23-9E	Jan. 1925	2,500	110,077		73	Bartlesville	2,525	75	Sandstone
Seeley-Wick, 22-22-11	Jan. 1922	7,000	357,576		327	Bartlesville	1,930	45	Sandstone
Smith-Jobe (near Blackwell) 10-24-13E	Sept. 1938			627	1	Mis. Lime	1,662	3	Lime
Teeter, 36-22-9	Jan. 1922	4,000	270,465		207	Bartlesville	2,400	150	Sandstone
Teichgraber, 2-25-8E		900	20,623		21	Bartlesville	2,450		Sandstone
Thrall, 28-23-10	1921	7,000	187,851		255	Bartlesville	2,190	166	Sandstone
Virgil, 13-24-12	Jan. 1916	4,800	126,984		130	Bartlesville Mis. Lime	1,550 1,700		Sandstone Lime
Virgil North, 3-23-13E		8,000	455,732		280	Bartlesville Mis. Lime	1,550 1,700		Sandstone Lime
Wiggins, 7-24-11E	Jan. 1925	2,500	56,787		46	Bartlesville	1,860	15	Sandstone
Wilkerson, 6-25-9E		1,300	18,524		15	Bartlesville	2,300		Sandstone
Willard, 7-27-11E		1,000	14,355		3				
Harvey County			1,060,839	18,725,647	144				
Halstead, 36-22-2W	Aug. 1928	1,200	232,050	868,706	21	Chat	2,972	33	Insol. Res.
Hesston,[6] 7-22-1W									

[4] Abandoned 1936.
[5] Taken out of Stumps during 1938. See Rice County.
[6] This pool now included with Graber McPherson County.

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production In 1938	Production Cumulative	Number of Wells Producing	Producing Horizon Name	To Top, Ft.	Thickness, Ft.	Character
Hollow-Nikkel, 30-22-3W	Dec. 1931	1,500	738,832	17,672,417	116	Lans. K. C.	2,499	21	Lime
						Chat	3,195	13	Insol. Res.
						Hunton	3,507	2	Lime
						Wilcox	3,500	14	Sandstone
						Arbuckle			Dolomite
Sperling, 23-22-2W...	Jan. 1935	500	89,957	184,524	7	Hunton	3,279	6	Lime
						Wilcox	3,447	16	Sandstone
Walton, 4-23-2E.....	Dec. 1923	Abandoned 1936							
Kingman County.......									
Cunningham, 30-27-10	Jan. 1931	1,200	218,244	1,663,548	36	Lans. K. C.	3,390	74	Lime
						Viola	3,925	33	Lime
						Wilcox	4,055	39	Sandstone
						Arbuckle	4,094	15	Dolomite
Kingman, 16-27-7W..	Jan. 1925		Abandoned			Chat	3,853	41	Insol. Res.
Shepherd, 10-27-10...	Dec. 1938	40	Shut in		1	Tonganoxie	3,500	10	Sandstone
Lyon County..........									
Fankhouser, 33-21-12E.........			49,943		66	Bartlesville	1,775	50	Sandstone
McPherson County.....			3,961,773	59,597,577	555				
Bornholdt, 30-20-5W.	Aug. 1937	40	9,001	10,648	1	Chat	3,292	43	Insol. Res.
Canton North, 26-18-1W.........	July 1936	40	8,851	33,678	1	Chat	2,803	29	Insol. Res.
Chindberg, 18-19-2W	Jan. 1929	700	158,146	1,007,495	6	Lans. K. C.	2,363		
					23	Chat	3,007	2	
Graber, 32-21-1[7].....	May 1934	2,400	1,089,252	3,132,333	3	Chat			Insol. Res.
					3	Misener	3,323	3	Sandstone
					112	Hunton	3,274	24	Lime
					1	Wilcox	3,398	8	Sandstone
Hesston,[8] 7-22-1W...									
Johnson, 35-19-3.....	Feb. 1932	1,200	262,350	2,362,350	15	Chat	3,032	14	Insol. Res.
Lindsborg, 8-17-3W..	Jan. 1938	160	4,057	4,057	2	Viola	3,352	21	Lime
McPherson, 29-18-2..	Sept. 1926	2,000	75,163	773,105	33	Lans. K. C.	2,340	55	Lime
						Chat	2,967	11	Insol. Res.
						Viola	3,140	60	Lime
Ritz-Canton, 1-20-2W	July 1929	13,000	1,610,363	30,460,723	242	Lans. K. C.	2,360	39	Lime
						Chat	2,935	31	Insol. Res.
						Viola	3,412	2	Lime
						Wilcox	3,440	4	Sandstone
Roxbury, 18-17-1W..	Nov. 1938	40	560	560	1	Chat	2,684	5	Insol. Res.
Voshell, 9-21-3.......	Aug. 1929	3,500	744,030	21,812,628	112	Chat	3,095	13	Insol. Res.
						Viola	3,301	3	Lime
						Wilcox	3,322	3	Sandstone
						Arbuckle	3,384	10	Dolomite
Marion County........			318,816		148				
Covert-Sellers, 1-21-4E	Sept. 1920	2,400	56,028	8,100,000 est.	25	Viola	2,330	5	Lime
Florence, 20-21-5E...	Dec. 1929	3,000	45,406	8,000,000 est.	19	Viola	2,300	10	Lime
Hillsboro, 12-19-2E..	Oct. 1927	300	67,578		14	Viola	2,800	18	Lime
Lost Springs, 22-17-4E..........	Sept. 1926	2,400	118,078		49	Chat	2,365		Insol. Res.
Peabody, 5-22-4E....	Sept. 1929	3,000	31,726		41	Viola	2,532		Lime
Ness County...........									
Aldrich, 7-18-25W...	Oct. 1929	1,800	36,667	55,841	10	Ft. Scott	4,378	21	Lime
						Mis. Lime	4,428	2	Lime
Pawnee County........									
Pawnee Rock, 13-20-16..........	Sept. 1936	640	28,191	38,067	6	Arbuckle	3,825	16	Dolomite
Pratt County..........									
Iuka, 11-27-13W.....	Aug. 1937	160	16,802	19,723	3	Simpson	4,292	7	Dolomite
Reno County..........			4,226,220	28,059,641	528				
Abbyville, 24-24-8W.	Jan. 1927	1,200	37,583	319,273	4	Lans. K. C.	3,540	9	Lime
Buhler, 25-22-5W....	Apr. 1938	160	34,119	34,119	2	Simpson	3,897	5	Sandstone
Burrton, 23-23-4.....	Feb. 1931	5,000	3,452,818	24,863,307	349	Chat	3,266	42	Insol. Res.
					96	Hunton	3,583	6	Lime
					1	Wilcox	3,723	4	Sandstone
					[illegible]	Arbuckle	3,775	9	Dolomite
Hilger, 16-26-4......	Mar. 1934	600	305,255	1,258,859	34	Viola	4,062	5	Lime
Lerado, 11-26-9......	Dec. 1935	1,800	383,615	1,530,415	1	Lans. K. C.	3,535	4	Lime
					33	Viola	4,128	28	Lime
Nickerson[9]..........									
Yoder, 34-24-5......	Oct. 1935	500	12,830	53,668	6	Chat	3,450	51	Insol. Res.
Rice County..........			7,801,945	39,737,132	764				
Bowman[9]..........									

[7] Includes Hesston for 1938.
[8] Included with Graber.
[9] Abandoned.

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production: In 1938	Production: Cumulative	Number of Wells Producing	Producing Horizon: Name	To Top, Ft.	Thickness, Ft.	Character
Brandenstein, 10-19-10	Nov. 1933	160	16,905	326,421	2	Lans. K. C.	3,014	12	Lime
Bredfeldt, 7-18-9W	Apr. 1937	40	5,154	9,166	1	Arbuckle	3,223	17	Dolomite
Campbell, 28-19-9W	Jan. 1938	160	21,900	21,900	3	Arbuckle	3,195	13	Dolomite
Chase, 32-19-9	Mar. 1931	4,800	3,137,158	16,973,246	3	Lans. K. C.	2,942	12	
					223	Arbuckle	3,246	38	Dolomite
Cramm, 15-19-9W	July 1937	160	41,900	58,543	3	Lans. K. C.	2,876	71	Lime
					1	Arbuckle			Dolomite
Cramm North, 15-19-9	July 1938	160	10,018	10,018	3	Arbuckle	3,241	10	Dolomite
Doran, 13-19-10	Sept. 1936	160	22,398	75,664	4	Arbuckle	3,291	20	Dolomite
Edwards, 3-18-8W	Jan. 1936	1,500	396,968	1,074,718	41	Arbuckle	3,278	5	Dolomite
Galt	Oct. 1935	40	Abandoned						
Geneseo, 25-18-8W	May 1934	3,000	1,012,221	2,539,224	103	Arbuckle	3,132	40	Dolomite
Guldner, 16-18-9W	July 1935	160	20,818	213,174	3	Lans. K. C.	2,884	14	Lime
						Arbuckle	3,227	3	Dolomite
Habiger,[10] 5-18-10W	Sept. 1937				24	Lans. K. C.	3,001	15	Lime
					4	Arbuckle	3,239	9	Dolomite
Haferman, 6-19-9W	June 1936	500	61,088	277,893	6	Arbuckle	3,192	24	Dolomite
Heinz, 8-18-10W	July 1938 Sept. 1938	80	5,902	5,902	1	Lans. K. C.	3,000	19	Lime
					1	Arbuckle	3,254	14	Dolomite
Keesling, 10-20-9W	Apr. 1935	600	316,243	2,044,086	40	Arbuckle	3,239	26	Dolomite
Orth, 27-18-10	July 1932	600	73,775	510,177	2	Lans. K. C.	2,915	21	Lime
					9	Quartzite	3,240	3	pre-Cambrian
Ploog, 33-18-9	June 1930	300	72,605	1,014,040	10	Arbuckle	3,252	19	Dolomite
Ponce, 28-21-7W	Apr. 1936	40		15,041	1	Conglomerate	3,388	40	Conglomerate
Proffitt, 12-20-10	Dec. 1938	40			1	Arbuckle	3,227	8	Dolomite
Raymond, 21-20-10	June 1929	1,000	321,029	5,292,213	4	Lans. K. C.	3,130	10	Lime
					37	Arbuckle	3,330	21	Dolomite
Rickard, 22-18-9	Oct. 1935	40	7,942	37,930	1	Wilcox	3,285	20	Sandstone
						Arbuckle	3,324	41	Dolomite
Silica[11]									
Soeken, 10-19-9	Jan. 1937	40	2,676	6,638	1	Lans. K. C.	2,905	18	Lime
Stumps, 4-18-10W	May 1935	1,200	629,466	954,941	21	Arbuckle	3,229	38	Dolomite
Welch, 2-21-6W	Apr. 1924	1,500	156,346	3,957,120	31	Chat	3,370	44	Insol. Res.
Welch North, 23-20-6W	June 1937	160	11,512	21,261	3	Chat	3,334	32	Insol. Res.
Wenke, 7-20-10	Mar. 1935	300	59,941	158,437	7	Arbuckle	3,360	13	Dolomite
Wenke West, 18-20-10	Oct. 1938	40	376	376	1	Arbuckle	3,292	5	Dolomite
Wherry, 11-21-7W	Sept. 1933	6,000	1,371,563	4,106,674	165	Conglomerate	3,358	22	Conglomerate
Wherry East, 12-21-7W	Sept. 1937	160	26,041	32,329	3	Conglomerate	3,455	14	Conglomerate
Rooks County			204,950	562,614	28				
Dopita, 31-8-17	Apr. 1934	160	13,061	40,050	1	Lans. K. C.	3,212	5	Lime
					3	Arbuckle	3,409	10	Dolomite
Faubin, 12-6-18W	Feb. 1936	80	7,500	25,890	2	Lans. K. C.	3,128	22	Lime
Kruse, 3-10-16W[12]	Jan. 1928	40	2.409	8,611	1	Lans. K. C.	3,115	6	Lime
Laton, 11-9-16	July 1927	200	47,326	247,326	6	Lans. K. C.	3,228	33	Lime
Nyra, 9-9-17W	Aug. 1937	40			1	Lans. K. C.	3,255	5	Lime
						Lans. K. C.	3,302	24	Lime
Stockton, 26-7-17W	Apr. 1937	160	8,137	15,815	2	Lans. K. C.	3,118	62	Lime
Webster[13]									
Westhusin, 11-9-17	Nov. 1936	300	105,965	152,223	7	Lans. K. C.	3,231	11	Lime
Zurich, 26-10-19	Sept. 1935	200	20,552	72,699	5	Lans K. C.	3,340	9	Lime
Rush County			432,755	699,041	20				
Otis, 10-18-16	July 1934		420,382	663,137	17	Reagan	3,527	9	Sandstone
Winget, 15-16-16	Dec. 1936	80	12,373	35,904	3	Lans. K. C.	3,243	4	Lime
Russell County			10,866,874	46,872,023	1,016				
Allon, 21-14-14	July 1937	240	46,314	56,172	6	Lans. K. C.	3,008	47	Lime
Anschutz, 10-15-13	Apr. 1936	80	14,973	62,387	2	Arbuckle	3,311	16	Dolomite
Atherton, 30-13-14	July 1935	400	134,164	310,615	9	Lans. K. C.	3,008	47	Lime
					10	Arbuckle	3,284	5	Dolomite
Balta, 32-13-14	Mar. 1936	120	18.522	87,941	3	Lans. K. C.	3,039		Lime
						Arbuckle	3,301	12	Dolomite
Balta North, 29-13-14W	July 1938	160	8,469	8,469	3	Arbuckle	3,311	6	Dolomite
Benso, 9-14-15	Feb. 1936	40	4,406	20,177	1	Lans. K. C.	3,030	66	Lime
Berrick[14]	Dec. 1935								

[10] Production included with Stumps (old pool reestablished).
[11] See under Barton County.
[12] Abandoned but reinstated in 1938.
[13] Abandoned 1938.
[14] Joined to Hall in 1938.

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production: In 1938	Production: Cumulative	Number of Wells Producing	Producing Horizon: Name	To Top, Ft.	Thickness, Ft.	Character
Big Creek, 36-14-15W	July 1935	900	310,592	969,163	2	Lans. K. C.	2,908	42	Lime
					25	Gorham	3,152	5	Sandstone
					6	Arbuckle	3,171	5	Dolomite
Big Creek East, 31-14-14W	July 1938	40	4,232	4,232	1	Arbuckle	3,149	4	Dolomite
Boxberger, 36-15-15	Dec. 1935	160	17,371	103,523	4	Lans. K. C.	3,147	4	Lime
Bunker Hill, 31-13-12	Oct. 1935	160	14,979	43,467	3	Lans. K. C.	2,965	16	Lime
Coralena, 17-15-13	Oct. 1936	600	252,613	455,853	6	Lans. K. C.	2,790	91	Lime
					20	Arbuckle	3,183	5	Dolomite
Coralena East, 9-15-13	July 1938	80	6,042	6,042	2	Lans. K. C.	3,000	64	Lime
Coralena South, 17-15-13	July 1938	40	4,061	4,061	1	Arbuckle	3,228	4	Dolomite
Donovan, 10-15-15	Feb. 1935	40	3,623	20,011	1	Lans. K. C.	3,193	7	Lime
Dubuque, 34-15-12	Oct. 1935	160	21,179	116,222	2	Arbuckle	3,275	3	Dolomite
Eichman, 34-15-13	May 1935	800	166,217	538,585	8	Arbuckle	3,316	10	Dolomite
Fairfield, 22-15-13W	Dec. 1938	40			1	Arbuckle	3,352	25	Dolomite
Fairport, 8-12-15W	Nov. 1923	3,600	674,127	13,164,474	149	Lans. K. C.	2,950	12	Lime
						Gorham	3,211	6	Sandstone
Foster, 19-15-15W	May 1938	40	5,020	5,020	1	Lans. K. C.	3,114	2	Lime
Gideon, 8-15-14W	June 1930	40	4,530		1	P. B. C.	3,266	7	Conglomerate
Gorham, 5-14-15[15] / Gorham East	Oct. 1926	6,000	2,525,227	12,723,378	2	Tarkio	2,525	25	Lime
					11	Topeka	2,765	105	Lime
					140	Lans. K. C.	3,027	30	Lime
					2	Arbuckle	3,289	4	Dolomite
					128	Gorham	3,299	1	Sandstone
Green Vale, 4-15-12W	Apr. 1938 / Nov. 1938	160	11,747	11,747	4	Lans. K. C.	3,040	5	Lime
					1	Arbuckle	3,267	21	Dolomite
Gurney, 23-14-14	Mar. 1935	600	124,883	418,281	1	Topeka	2,675		Lime
					12	Lans. K. C.	3,001	5	Lime
					2	Pre-Camb.			Granite
Gurney South, 35-14-14W	Oct. 1936	320	141,282	312,408	6	Lans. K. C.	2,890	5	Lime
						Lans. K. C.	2,961	10	Lime
					8	Gorham	3,165	3	Sandstone
Hall, 30-14-13	Oct. 1931	1,200	368,973	1,150,928	42	Lans. K. C.	2,985	100	Lime
						Arbuckle	3,451	3	Dolomite
					12	Reagan	3,129	1	Sandstone
					1	Pre-Camb.	3,156	25	Granite
Hall North[16]									
Karst, 27-15-14W	Oct. 1935	160	33,675	119,195	4	Arbuckle	3,315	4	Dolomite
Letch, 34-14-13W	July 1936	1,200	319,701	396,396	1	Tarkio	2,396		Lime
					40	Lans. K. C.	2,831	49	Lime
Letch South, 34-14-13W	Aug. 1938	40	3,511	3,511	1	Lans. K. C.	2,916	10	Lime
Michel, 36-14-14	July 1937	160	25,178	39,981	1	Topeka	2,852	11	Lime
					3	Lans. K. C.	2,901	45	Lime
Neidenthal, 23-14-15W	Aug. 1934	600	91,316	725,408	13	Arbuckle	3,246	4	Dolomite
Russell, 22-13-14	Feb. 1934	1,200	459,398	3,671,516	3	Lans. K. C.	3,195	9	Lime
					47	Arbuckle	3,280	6	Dolomite
Schneider, 35-15-14W	Nov. 1938	80	1,699	1,699	2	Arbuckle	3,349	6	Dolomite
Sellens, 26-15-13W	July 1929	1,200	227,891	2,004,127	30	Lans. K. C.	3,088	9	Lime
						Arbuckle	3,352	13	Dolomite
Smoky Hill, 2-15-14W	Feb. 1938	40	704	704	1	Lans. K. C.	2,950	9	Lime
Steinert, 21-15-15W	March 1936	40	7,058	26,732	1	Lans. K. C.	3,060	36	Lime
Trapp, 23-15-14	Oct. 1929	15,000	4,562,327	8,472,513	2	Topeka	2,889	7	Lime
					12	Lans. K. C.	3,062	2	Lime
					1	Congl.			Conglomerate
					319	Arbuckle	3,252	1	Dolomite
Trapp South[17]									
Trapp Southwest[17]									
Vaughn, 17-14-14	Apr. 1937	1,000	245,530	359,276	21	Lans. K. C.	3,004	30	Lime
					1	Gorham	3,282	7	Sandstone
					4	Arbuckle			Dolomite
Williamson, 9-14-14	Feb. 1936	160	8,851	29,717	2	Tarkio	2,522	28	Lime
Scott County									
Shallow Water, 15-20-33	Dec. 1934	600	341,056	492,502	8	Mis. Lime	4,670	16	Lime
Sedgwick County			1,411,292	40,554,947	266				
Andover South, 36-27-2E	Nov. 1937	80	11,064	11,064	3	Wilcox	3,098	1	Sandstone
Bentley, 19-25-1W	Apr. 1934	40	1,338	6,453	1	Lans. K. C.	2,911		Lime

[15] Includes Dumler, Milberger, Petersen and Sullivan.
[16] Merged with Hall 1938.
[17] Merged with Trapp 1938.

TABLE 1.—(*Continued*)

Field and Location	Discovery Date	Area, Acres	Production: In 1938	Production: Cumulative	Number of Wells Producing	Producing Horizon: Name	To Top, Ft.	Thickness, Ft.	Character
Cheney[18]									
Cross, 27-25-1W	Apr. 1929	160	11,162	62,300	2	Lans. K. C.	2,690	40	Lime
Eastborough North, 8-27-2E	Aug. 1938	80	No runs		2	Viola	3,258	4	Lime
Eastborough, 19-27-2E	Aug. 1929	1,000	251,291	7,467,956	46	Chat	2,956	14	Insol. Res.
						Viola	3,238	4	Lime
Goodrich, 16-25-1E	Dec. 1928	640	267,979	2,117,900	32	Lans. K. C.	2,614	2	Lime
						Chat	3,010	10	Insol. Res.
						Viola	3,334	3	Lime
Greenwich, 14-26-2E	May 1929	700	361,942	8,875,597	43	Chat	2,865	3	Insol. Res.
						Viola	3,321	5	Lime
						Wilcox			Sandstone
Kuske, 24-25-1E	Jan. 1929	40	319	132,880	1	Burgess	3,489	2	Conglomerate
Oatville, 18-28-1E	Nov. 1937	40	5,216	5,216	1	Wilcox	3,489	2	Sandstone
Robbins, 20-28-1E	June 1929	420	148,856	2,660,167	56	Chat	3,090	12	Insol. Res.
Valley Center, 1-26-1W	Aug. 1928	1,500	352,125	19,215,414	78	Misener	3,368	7	Conglomerate
						Lans. K. C.	2,579	13	Lime
						Viola	3,366	2	Lime
Stafford County			1,378,907	4,479,507	198				
Bonham, 28-25-12W	Apr. 1938	40			1	Arbuckle	4,210	10	Dolomite
Drach, 12-22-13W	Nov. 1937	800	67,043	68,733	11	Arbuckle	3,693	12	Dolomite
Fischer, 31-21-12W	May 1938	120	6,939	6,939	3	Arbuckle	3,641	7	Dolomite
Gates, 27-21-13W	May 1933	640	71,063	391,028	11	Arbuckle	3,679	39	Dolomite
Jordan, 15-25-14W	Nov. 1936	160	45,518	96,687	4	Lans. K. C.	3,722	5	Lime
Kipp, 27-25-14W	Jan. 1937	80	17,715	39,916	2	Lans. K. C.	3,827	79	Lime
Leesburgh, 12-25-13W	Apr. 1938	40	None	None	1	Arbuckle	4,153	10	Dolomite
Max, 35-21-12W	Aug. 1938	40	477	477	1	Arbuckle	3,570	5	Dolomite
Mueller, 29-21-12	Mar. 1938	80	None	None	2	Arbuckle	3,594	7	Dolomite
Rattlesnake, 13-24-14W	Oct. 1938	40	2,379	2,379	1	Lans. K. C.	3,608	48	Lime
Richardson, 36-22-12W	Oct. 1930	1,200	530,318	2,915,246	59	Arbuckle	3,537	62	Dolomite
St. John, 23-24-13W	Apr. 1935	1,200	159,148	368,928	7	Lans. K. C.	3,588	32	Lime
					21	Arbuckle	4,075	12	Dolomite
Sittner, 33-21-12W	Aug. 1937	600	80,734	83,661	2	Lans. K. C.	3,278	136	Lime
					4	Arbuckle	3,600	6	Dolomite
Sittner South, 3-22-12W	May 1938	40	5,544	5,544	1	Arbuckle	3,594	6	Dolomite
Snider, 3-21-11W	Apr. 1936	320	26,341	122,514	4	Lans. K. C.	3,111	38	Lime
					3	Arbuckle	3,324	18	Dolomite
Snider South, 16-21-11W	Aug. 1938	40	2,699	2,699	1	Arbuckle	3,402	7	Dolomite
Zenith, 23-24-11W	Sept. 1937	2,100	362,989	374,756	97	Misener	3,804	20	Sandstone
Sumner County			1,769,837	38,573,075	277				
Anness, 2-30-4	Oct. 1937	40	7,432	22,598	1	Wilcox	4,394	7	Sandstone
Caldwell, 17-35-3W	May 1929	160	52,789	1,217,760	4	Wilcox	4,765	19	Sandstone
Churchill, 25-31-2E	July 1926	1,000	253,510	17,947,992	69	Stalnaker	1,820	25	Sandstone
Latta, 9-30-2W	June 1927	160	40,457		7	Kansas City	3,042	14	Lime
							3,200	10	Lime
Nevitt, 36-32-2E	July 1937	40			1	K. C. Lime	2,608		Lime
Oxford, 23-32-2E	Aug. 1927	800	431,341	13,734,035	15	Stalnaker	2,020		Sandstone
					6	Layton			Sandstone
					42	Arbuckle	2,890	3	Dolomite
Oxford West, 17-32-2	May 1926	160	12,305	459,499	4	Arbuckle			Dolomite
Padgett, 23-34-2E	Oct. 1924	1,800	89,243	1,689,243	22	Chat	3,474	28	IR
Rainbow Bend West, 24-33-2E		160			2	Burbank			Sandstone
						Arbuckle			Dolomite
Rutter, 21-33-2E	July 1926	40	12,990	26,591	1	Chat	3,315		IR
Tate, 31-32-2E[19]	Aug. 1938		1,370	1,370	1	Simpson	3,722	7	Sandstone
Vernon North, 15-35-2E	July 1915	200	44,979	145,881	5	Chat	3,443	22	IR
Wellington, 33-31-1W	Dec. 1929	1,200	819,977	3,324,662	97	Chat	3,655	11	IR
Zyba, 7-30-1E	Nov. 1937	40	3,444	3,444	1	Wilcox	3,866	3	Sandstone
Trego County			88,795		14				
Gugler, 36-12-21W	Dec. 1936	40	4,766	9,808	1	Arbuckle	3,830	8	Dolomite
Rega, 20-13-21W	May 1929	40			1	P. B. C.	3,960	12	Conglomerate
Wakeeney, 14-11-23W	Oct. 1934	1,800	84,029	301,670	12	Lans. K. C.	3,619	8	Lime
Woodson County			329,595						
Big Sandy, 14-26-14E					20				
Hoagland, 2-24-14E					15				
Wiede, 32-23-15E					12				
Winterscheid, 15-23-14		7,700	267,000		225	Mis. Lime	1,575	65	Lime

[18] Abandoned in 1938.
[19] Abandoned.

Ritz Canton field). As might be expected, most of the repressuring is done in the old areas of eastern Kansas in Chautauqua, Allen, Bourbon, Elk, Crawford, Neosho, Anderson and Linn Counties. However, a number of wells are in pools of Greenwood, Butler, Sumner and Cowley Counties. Very few wells are being repressured in McPherson and Sedgwick Counties.

Acidization.—The use of acid continues to be important in the production of Kansas wells. Inasmuch as the greater portion of the present

TABLE 2.—*Producing Gas Fields in Kansas in* 1938

Field and Location	Discovery Date	Area, Acres	Production Millions Cu. Ft.		Number of Wells Producing	Producing Horizon			
			In 1938	Cumulative		Name	To Top, Ft.	Thickness, Ft.	Character
Barber County									
Medicine Lodge 13-33-13W	Jan. 1927	5,000	5,085	60,928	23	Chat	4,455	10	Insol. Res.
Barton County									
Albert	Jan. 1935	(See Otis in Rush)							
Clark County									
Morrison 21-32-21W	Nov. 1928	160			1	Conglomerate	5,443	32	Conglomerate
Haskell County									
Satanta		(See Southwest Kansas)							
Harvey County									
Sperling 23-22-2W	Jan. 1935	600	545	6,131	8	Chat	2,955	50	Insol. Res.
Kingman County									
Cunningham 30-27-10W	Aug. 1930		1,127		4	Cottonwood Wabaunsee Viola Simpson Arbuckle	1,993 2,475 3,922 4,003 4,109	57 10 36 52 75	Lime Sandstone Lime Sandstone Dolomite
McPherson County									
Moundridge 12-21-2W	Mar. 1938	160			1	Mis. Lime	3,007	9	Lime
Pratt County									
Cairo 7-28-11W	Nov. 1935	1,800	219	567	3	Viola	4,278	8	Lime
Reno County									
Burrton 23-23-4W	Sept. 1930	5,000	6,100	30,536	52	Chat	3,298	70	Insol. Res.
Yoder 34-24-5W	Oct. 1935	800	900		4	Chat	3,402	50	Insol. Res.
Rice County									
Guldner 16-18-9W	June 1935	160	13		1	Lansing	2,884	10	Lime
Lyons 35-19-8W	Sept. 1937	1,800	2,209½	2,209½	5	Arbuckle			Dolomite
Orth 27-18-10W	July 1933	640	581		3	Lans. K. C.	2,906	30	Lime
Sterling 4-22-8W	Nov. 1937	40			1	Conglomerate	3,339	5	Conglomerate
Thurber 22-21-9W	Oct. 1937	160	549		1	Misener	3,317	10	Conglomerate
Rush County									
Otis 11-18-16W	Mar. 1930	15,000	6,800	36,453	58	Reagan	3,507	2	Sandstone
Sedgwick County									
Derby, 32-28-2E	Aug. 1937	160	85		3	Stalnaker	2,215	17	Sandstone
Sumner County									
Wellington 33-31-1W	Dec. 1929	1,200	1,049		97	Chat	3,655	12	Insol. Res.
Various Counties in Southwest Kansas									
Hugoton 3-35-34W	1922	2 million	26,659	146,170	272	Big Blue	2,755	10	Lime

production comes from dolomites or limestones, there is a strong temptation to increase the porosity of the producing horizon by this chemical method. Whereas a shot of from 500 to 1000 gal. is common in eastern Kansas (for the Mississippi lime or the Kansas City lime), much larger amounts are used in western Kansas. During 1938 a number of wells

TABLE 3.—*Summary of Drilling Operations in Kansas*

Important Wildcats Drilled in 1938

County and Pool Name	Location	Discovery Well	Potential Production, Bbl.	Producing Horizon and Depth, Ft.
Barton:				
Boyd	3-18-14W	Long & Johnson No. 1 Eveleigh		Arbuckle 3365-67
Clawson	17-20-11W	Virginia Drl. Co. No. 1 Clawson	679	Arbuckle 3285-3294
Ellinwood West	7-20-11W	Ash No. 1 P. Schartz	473 nat.	Arbuckle 3346-3352
Hagan	20-20-11W	Pulse No. 1 Hagan	669 nat.	Arbuckle 3323-3330
Hoisington	21-17-13W	Brauck No. 1 Soderstrom Thayer No. 1B Soderstrom	1,065 423	Lans. K. C. } 3440-3462 Arbuckle }
Odin	10-17-12W	Price No. 1 Wondra	539	Arbuckle 3340-3342
Prusa	20-16-11W	Sinclair No. 1 Prusa	1,313	Arbuckle 3335-3352
Wolf	36-19-12W	Ash No. 1 Wolf estate	501	Arbuckle 3346-3374
Cowley:				
Dunbar	29-30-5E	Spencer No. 1 Dunbar	625	Kans. City 2229-2265
Frog Hollow East	21-32-5E	Blair No. 1 Dunlap	352	Bartlesville 3042-3054
Wilson	9-33-6E	Smith No. 2 Wilson	433	Arbuckle 3519-3523
Ellis:				
Bemis South	2-12-17W	Cities Service No. 1 Hall		Arbuckle 3592-3603
Burnett South	12-11-18W	Duwe Farris No. 1 Hadley	1,266	Arbuckle 3330-3333
Peavey	24-11-18W	Darby No. 1 Peavey		Arbuckle 3425-34
Richards	5-11-18W	Glimac No. 1 Richards	941	Lans. K. C. 3360-3373
Ellsworth, Schroeder	29-17-9W	Cities Service No. 1 Schroeder	2,644	Arbuckle 3205-3215
Finney, Nunn	27-21-34W	Atlantic No. 1 Nunn	604	Mis. Lime 4654-4664
Ford, Pleasant Valley	34-27-21W	Sincair No. 1 Young	Gas	Mis. Lime { 4890-4910 4985-90-95-98 T. D. 5995
Graham, Morel	15- 9-21W	Continental No. 1 Morel	2,105	Arbuckle 3718-3720
Kingman, Sheperd	10-27-10	Bunte Bros. No. 1 Sheperd	40	Tonganoxie 3500-3510
McPherson:				
Lindsborg	8-17-3W	Carter No. 1 Hoglund	345	Viola 3352-3373
Moundridge	12-21-2W	Drillers No. 1 Decker	Gas, 7,000 M cu. ft.	Mis. Lime 3007-3016
Roxbury	18-17-1W	West. Kans. No. 1 Fraternal	419	Mis. Lime 2684-89
Reno, Buhler	25-22-5W	Westgate No. 1 Johns	912	Wilcox 3895-3902
Rice:				
Cramm North	15-19-9W	Shell No. 1 Cramm		Arbuckle 3241-3251
Heinz	8-18-10W	Kaiser No. 1 Heinz Transw. No. 1C Habiger	1,041 183	Lans. K. C. 3000-3019 Arbuckle 3254-3268
Proffitt:	12-20-10W	Tatlock No. 1 Proffitt	299	Arbuckle 3327-3335
Wenke West	18-20-10W	Tatlock No. 1 Burchart	309	Arbuckle 3292-3297
Russell:				
Balta North	29-13-14W	Phillips No. 1 Miller	814	Arbuckle 3311-3317
Big Creek East	31-14-14W	Aylward No. 1 Solback	836	Arbuckle 3149-3153
Coralena East	9-15-13W	Shield No. 1 Rogg	588	Lans. K. C. 3000-3064
Coralena South	17-15-13W	Southern No. 1 Letch	1,172	Arbuckle 3228-3230
Fairfield	22-14-13W	Southern No. 1C. Sellens	153	Arbuckle 3352-3377
Foster	19-15-15W	Parks et al. No. 1 Foster	341	Lans. K. C. 3114-3116
Greenvale	4-15-12W	Jones et al. No. 1 Kuhnle Jones et al. No. 1A. Kuhnle	945 394	Lans. K. C. 3040-3045 Arbuckle 3267-3288
Letch South	34-14-13W	Coralena No. 1 Hefferman	758	Lans. K. C. 2916-2926
Schneider	35-15-15W	Wes. Kans. No. 1 Schneider	1,844	Arbuckle 3349-3355
Smoky Hill	2-15-14W	Coralena No. 1 Mithcell	1,139	Lans. K. C. 2950-2959
Sedgwick, Eastborough N	8-27-2E	Nat. Refg. No. 1 Trustee	420	Viola (Hunton?) 3258-3261
Stafford:				
Bonham	28-25-12W	Nat. Refg. No. 1 Bonham	330	Arbuckle 4204-4210
Fischer	31-21-12W	Sacco No. 1 Fischer	783	Arbuckle 3641-3648
Leesburgh	12-25-13W	Cont. No. 1 Fair	853	Arbuckle 4153-4162
Max	35-21-12W	Rowley No. 1 Max Sittner	1,213	Arbuckle 3570-3575
Mueller	29-21-12W	Torre & Feaster No. 1 Mueller	1,210	Arbuckle 3594-3602
Rattlesnake	13-24-14W	Atlantic No. 1 Wise	85	Lans. K. C. 3644-3656
Sittner South	3-22-12W	Stano. No. 2 Siefkes	2,221	Arbuckle 3594-3601
Snider South	16-21-11W	Cities Service No. 1 B. Smith	404	Arbuckle 3402-3409
Sumner, Tate	31-32-2E	Murphy No. 1 Tate	116	{ Wilcox 3722-3736 Abandoned

in the Letch pool, Russell County, were treated with 10,000-gal. shots and in one case 20,000 gal. was used. This probably constitutes a record up to date for Kansas. A well drilled by the Lario Oil Co. in the Shutts pool (No. 3 Marshall in 31-11-17) came in with a production of less than one barrel of oil per hour. After being treated with three shots of 500, 1000 and 3000 gal., respectively, it responded with a production of over 100 bbl. per hour. This almost proves that a dry hole may be converted into a commercial producer.

Active Pools.—The most active pools of the year were the Zenith, Trapp, Silica and Bemis pools. The first of these proved most attractive because of the presence of a real sand (Misener) of considerable thickness. The Zenith pool now has over 97 wells and a potential productive capacity of over 208,000 bbl. per day. Similarly, the Trapp pool at the close of the year had 334 wells with a potential of over a half million barrels. It holds first honors in this respect. The Silica pool on the same date had 455 wells with a potential of 445,000 bbl. The Bemis pool was not far behind these top notchers with a potential of 435,000 bbl. from 218 wells.

Wildcatting.—Important dry holes were drilled in Thomas, Graham, Riley and Norton Counties. The Thomas County well furnished valuable geological information, although it is hard to interpret, because of the almost unbroken succession of limestones found below the Permian system. One well in Riley County (Coronado No. 1 Parks) gave geologists a start when it showed thick Hunton limestone immediately below the Pennsylvanian and also the absence of the Arbuckle between the Simpson and the pre-Cambrian. Two of the wildcats were successful in opening new pools. One of these was in Finney County, where the Atlantic Refining Co. discovered the Nunn pool. The other was in Graham County, where the Continental Oil Co. discovered oil in the Arbuckle limestone to open the Morel pool. As the year closed the greatest interest came to be attached to northeastern Kansas. The area known as the Forest City Basin, lying between the Nemaha Granite Ridge on the west and a similar ridge in northeastern Missouri, was being examined by every important oil company. All available geological information is being collected. Furthermore, an active leasing campaign is under way.

Acknowledgment

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Oil and Gas Development in Kentucky during 1938

By Coleman D. Hunter,* Iley B. Browning,† and Ralph Thomas‡

(New York Meeting, February, 1939)

Production of oil in Kentucky during 1938 was 5,566,154 bbl., showing a substantial increase over that of the year 1937; while in the gas areas development was somewhat retarded although deliveries were similar to those of 1937.

In eastern Kentucky there was an oil increase during 1938 of over 150,000 bbl. above that of 1937. No new pools were developed and the increase was almost entirely due to the installation and expansion of secondary recovery methods and to the further development of the Maxon and Big Lime, Mississippian pools in Floyd and Martin Counties. With this development eastern Kentucky reached a level near that of 12 years previous, when the development of several large producing areas had just been completed.

In eastern Kentucky during 1938 not over 50 gas wells were completed. Although the pipe-line deliveries were approximately the same as during 1937, development was retarded because of an excess of gas already developed and the intensive development of the Oriskany fields in West Virginia.

In western Kentucky, in the part of the Illinois Basin lying in the state and known in Kentucky as the Western Coal Basin, the increase was due to the discovery of a number of new pools, the largest and the one producing the biggest wells being known as the Birk City pool. In fact, the discovery of this pool with the McClosky "sand" (St. Genevieve limestone) as the producing formation was in a large measure responsible for the increased activity, which in turn brought the discovery of the other areas.

The discovery well in this pool is the C. T. Blackwell, which came in flowing 1000 bbl. daily from the McClosky sand at a depth of 1870 ft., drilled in April 22, 1938. This discovery, coming at a time when the major companies and many others were conducting an intensive leasing campaign and making extensive subsurface and geophysical surveys in the deeper part of the basin, resulted in renewed activity over the entire area and brought much new drilling. It also brought to Kentucky for

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TABLE 1.—*Oil and Gas Production in Kentucky*

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[a]	To End of 1938	During 1938
1	Big Sinking, *Lee, Estill, Powell, Wolfe*	19	14,100		38,058,*xxx*	740,*xxx*[1]
2	Ida May, *Lee*	13	377		703,2*xx*	74,048[2]
3	Pebworth, *Owsley*	15	60		71,*xxx*	2,*xxx*
4	Ross Creek, *Estill*	21	468		805,167	17,851
5	Goocey, *Lee*	18			75,5*xx*	1,*xxx*
6	Trabue, *Lee*	9			120,*xxx*	12,237
7	Ashley, *Powell*	21	1,091		3,087,*xxx*	76,836
8	Irvine, *Estill*	23	4,7*xx*		13,*xxx*,*xxx*	160,*xxx*
9	Wagesville, *Estill*	21	400		450,127	17,124
10	Campton-Stillwater, *Wolfe*	26	1,447		662,113	9,904
11	Buffalo Cr. Oil Pool, *Owsley*	16	12		32,*xxx*	2,*xxx*
12	Island Creek, *Owsley*	11	20		9,899	0
13	Olympia, *Bath*	21	(Depleted.	Abandoned since	1920)	
14	Menifee Oil, *Menifee*	18	(Abandoned.	Wells pulled)	231,835	
15	Ragland Oil, *Bath, Rowan*	37[3]			258,930	
16	Cannel City, *Morgan*	26	600		378,507	678
17	Oil Springs, *Johnson, Magoffin*	19	6,100		9,255,798	222,097[4]
18	Burning Fork, *Magoffin*	16	918		1,759,981	52,174[5]
19	Blaine, *Lawrence, Johnson*	20	6,820		15,543,886	480,937
20	Elna, *Johnson*	18			1,593,165	39,334
21	Louisa Pool, *Lawrence*	26	1,*xxx*	600	1,568,193	34,649
22	Floyd Gas, *Floyd*	35	See Beaver Cr.	229,500		
23	Isonville, *Elliott*	22	146	2,000	86,991	3,096
24	Big Sandy Oil, *Floyd, Knott*	21	160		218,*xxx*	48,285
25	McKinney, *Lincoln*	17			4,502	0
26	Pike County Gas Field, *Pike*	8		57,000		

[a] Footnotes to column heads and explanation of symbols are given on page 250.

[1] Increase in Lee, Powell and Estill Counties due to repressuring, reconditioning, acidizing and new inside drilling. Of the 10 pools that make up the Big Sinking pool, there was an increase in production in all but two.

[2] Increase in production due to new wells and repressuring.

[3] Depleted. Abandoned in 1931.

[4] Increase in production due to repressuring.

[5] Natural decline.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.: To End of 1938	Total Gas Production, Millions Cu. Ft.: During 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	Number of Oil and/or Gas Wells: During 1938: Completed	Number of Oil and/or Gas Wells: During 1938: Abandoned	Number of Oil and/or Gas Wells: At End of 1938: Producing Oil[b]	Number of Oil and/or Gas Wells: At End of 1938: Producing Gas[c]	Oil-production Methods at End of 1938, Number of Wells: Flowing	Oil-production Methods at End of 1938, Number of Wells: Pumping	Oil-production Methods at End of 1938, Number of Wells: Miscellaneous	Pressure, Lb. per Sq. In.[d]: Initial	Pressure, Lb. per Sq. In.[d]: Average at End of 1937	Pressure, Lb. per Sq. In.[d]: Average at End of 1938	Character of Oil, Approx. Average during 1938: Gravity A.P.I. at 60° F., Weighted Average
1			2,5*xx*	4*x*		2,5*xx*			2,2*xx*	[13]				40
2				1*x*		12*x*			11*x*					
3						15								
4						18*x*			8*x*					
5						13			11					
6			15			15			15					41
7			523			523			4*xx*					
8			1,1*xx*			1,0*xx*			1,0*xx*					
9						150			3*x*					
10			275			275			7*x*					
11			7			4			4					41.8
12			6	0										39
13			20											
14			150											
15	100					100								
16			75			75			11	[13] [12]				
17			1,055			1,055			1,033	20[14]	180	300	300	36.5
18			159			159			159					36.5
19			1,118			1,118			1,118		550	*y*	360	36.5
20			250			250			230					36.5
21			286			286			234					38.5
22	*y*	*y*	1,26*x*[6]	3*x*	1*x*		1,245							
23			39	2		26	8		23					
24			61	10	0	55		2	6	39[14]				
25			8	0	0[7]	4	4							
26	*y*	*y*	19*x*	10	0		19*x*							

[6] Does not include oil wells. See Beaver Creek.
[7] Field has been abandoned.
[12] Injection into reservoir.
[13] Acid treatment has not been successful in this field.
[14] Gas lift.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1938		Reference to Text[i]
	Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.	
1	Corniferous	Dev, Sil	700–1,200	650–1,150	S, LS	Por	30	MC	Tren	2,*xxx*	
2	Corniferous	Dev, Sil	1,000–1,200	975–1,175	S, LS	Por	20±	MC	Dev		
3	Corniferous	Dev			LS	Por	20±	MC	Dev		
4	Corniferous	Dev, Sil	550–900	520–870	LS	Por	20±	T	Ord		
5	Corniferous	Dev, Sil			LS	Por	20±		Dev		
6	Corniferous	Dev, Sil	940–1,140	900–1,100	LS	Por	20±	MC			
7	Corniferous	Dev, Sil	600–1,100	550–950	LS	Por	40±	AF			
8	Corniferous	Dev, Sil	120–1,000	85–960	LS	Por	40±	AF	Ord		
9	Corniferous	Dev, Sil	100–400	75–375	LS	Por	25±	AF	Ord		
10	Corniferous	Dev			LS	Por	25±	AD	Dev	2,190	
11	Big Lime	Mis			LS	Por	15	A	Dev	1,962	K.G.S.—"New Oil Pools in Ky."
12	Big Lime	Mis			L	Cav	10–40	MC	Dev		
13	Silurian				L	Cav	10±	MC	Ord		
14	Corniferous	Dev	1,040–1,250	1,020–1,230	LS	Por	20±	MC	Ord		
15	Corniferous	Dev	650–850	625–825	LS	Por	25±	SC	Ord		
16	Corniferous	Dev	1,800–2,000	1,780–1,980	L	Por	20±	AF	Dev		
17	Weir	Mis	900–1,260	860–1,220	S	Por	35	DA	Ord	3,815	
18	Weir	Mis	1,080–1,400	1,040–1,360	S	Por	30	D	Ord	3,900	
19	Weir	Mis	760–1,060	700–1,000	S	Por	60	D	Sil		
20	Weir, Berea	Mis	640–1,100	600–1,060	S	Por	30	DF A S	Dev		
21	Berea	Mis	1,600–1,900	1,575–1,875	S	Por	20±	S	Ord	4,975	Owens Bottling Co.
22	Salt sand, Maxon, Big Lime, Big Injun, Devonian shale, Corniferous, LS.	Pen Mis, Dev	1,100–3,500	900–3,100	S, L, LS, H	Por, Cav	15–550	A-D MC T-N S	Sil	3,643	
23	Weir	Mis, Dev	875–1,500	825–1,350	S, H, LS	Por	40± 20± 350±	A	Dev	1,780	
24	Maxon, Big Lime, Big Injun	Mis	1,000–1,500	950–1,475	S, LS	Por, Cav	15±	ML MC T	Ord	3,706	
25	Corniferous	Dev	121–360	101–390	LS	Por	18±	MC	Ord	855	Jillson,—K.G.S., Series VI, 1922
26	Devonian shale, Salt sand, Maxon, Big Lime, Big Injun	Pen, Mis Dev			S-L H	Por, Cav	10–800	A-Am H-MC D-T-S	Dev	4,181	

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[a]	To End of 1938	During 1938
27	Martin Co. Oil & Gas, *Martin*	41	210	87,900	118,315	93,871
28	North Triplett Gas, *Rowan*	34		1,200		
29	Knott Co., *Knott*	33	40	111,000		
30	Boyd Co. and Ashland, *Boyd*	14		16,640		
31	Perry Gas (Hazard), *Perry*	8		1,400		
32	Oneida-Burning Springs, *Clay*	13		7,000		
33	Burning Springs Gas, *Clay*	29				
34	Indian Creek Gas, *Knox*	9	0	1,200 4,600 EW.		
35	Artemus-Himyar Gas, *Knox*	8		5,000		
36	Red Bird Gas, *Bell*	8		600		
37	Williamsburg Oil & Gas Pool, *Whitley*	36[9]	700		4,000	
38	Big 6 Gas, *Breathitt*	18[10]		1,600		
39	Rothwell Gas, *Menifee*	37[11]		15,360		
40	Powell Gas, *Powell*	6				
41	Carlisle Gas, *Gallatin, Carroll*	6				
42	Swamp Br. Gas, *Johnson*	11	3	3,000	Not marketed	0
43	Flat Gap Gas, *Johnson*	18		10,880		
44	Win Gas, *Johnson*	21		1,980		
45	Cain, *Lawrence*	9		550	0	0
46	Ivy-Licking and Mine Fork Gas, *Magoffin*	18		6,840		
47	Green-Taylor Gas, *Green, Taylor*	17	Abandoned			
48	Cumberland-Clinton, *Cumberland, Clinton*	Abandoned.	No Production			
49	Little Richland, *Knox*					

[9] Field abandoned.
[10] All but three wells in field abandoned.
[11] Used for storage.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					Oil-production Methods at End of 1938			Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1938
				During 1938		At End of 1938		Number of Wells				Average at End of		Gravity A.P.I. at 60° F.
	To End of 1938	During 1938	Completed to End of 1938	Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Flowing	Pumping	Miscellaneous	Initial	1937	1938	Weighted Average
27	*y*	*y*	314	8	0	26	282	4	10					38
28			17				10				45			
29	*y*	*y*	226	12	0		226							
30	*y*	*y*	216	0	2*x*	2	214				*y*	*y*	*y*	
31	*y*	*y*	7	0	0		7							
32	*y*	*y*	32	2			26				305			
33	*y*	*y*	5				5[8]							
34	*y*	*y*	7	1										
35	*y*	*y*	19	0	0		9				310	310	310	
36			3				3							
37			30	0	0	25	5				240			
38	*y*	*y*	14	0	1		3							
39	*y*	0	8*x*											
40			2*x*	2			2*x*							
41							17				160		20	
42	*y*	*y*	22	0	0	2	19							
43	*y*	*y*	2*xx*	0	2*x*									
44	*y*	*y*	28		2*x*									
45	0	0	9				9							
46	*y*	*y*	104	0			104							
47			1*xx*				1*xx*							
48														
49														

[8] Gas from this field is used only locally, for domestic purposes.

TABLE 1.—(*Continued*)

Line Number	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zones	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938: Name	Deepest Zone Tested to End of 1938: Depth of Hole, Ft.	Reference to Text[i]
27	Oil-Maxon, Gas Salt sand, Maxon, Big Lime, Dev. shale	Pen, Mis, Dev	1,100–3,250	700–3,800	S-L-H	Por, Cav	10–600	A-AF-D-T-MC-S	Dev		
28	Corniferous lime	Dev	350	335	LS	Por	11	MC	Ord	1,501	
29	Salt sand, Maxon, Big Lime, Big Injun, Devonian shale	Pen, Mis, Dev	1,300–3,500	1,250–3,000	S-L-H	Por, Cav	20–500	A-AM H-MC-D-T S	Ord		
30	Corniferous, Salt sand, Maxon, Black shale	Pen, Mis, Dev	2,200±	1,650±	S-H-SL	Por	50± 400± 150±	T	Ord	4,669	K.G.S. Serv. VI, 1926—New Oil Pools in Kentucky
31	Salt sand, Big Lime, Brown shale	Pen, Mis, Dev	2,700–3,300	2,200–2,900	S-L-H	Por, Cav	50± 500±	MC	Dev	3,637	
32	Corniferous	Dev	1,550–1,700	1,525–1,675	LS	Por	20±	A. MC	Dev	2,284	
33	Corniferous	Dev			LS	Por	25±	A. D	Dev		
34	Big Lime	Mis	1,550	1,500	L	Cav	20	T	Mis	1,552	
35	Maxon, Brown shale, Corniferous	Mis Dev	1,110–2,100	1,080–2,000	S-H-LS	Por	30± 175± 100±	A-AF-D	Dev	2,225	
36	Big Lime, Brown shale, Corniferous	Mis Dev	3,500±	3,400±	L-H	Cav, Por	100± 175± 50±	MC	Dev	3,725	
37	Salt sand Big Lime	Pen Mis	Oil 900± Gas 1,750±	850± 1,700±	SL	Por Cav	Oil 30± Gas 20±	A	Ord	3,350	Jillson, K.G.S. Serv. VI—New Oil Pools in Ky.
38	Big 6	Sil	1,750–1,900	1,725–1,875	S	Por	25±	A	Sil		
39	Corniferous Ragland sand	Dev	550–700	500–650	LS	Por	40±	D	Ord		
40	Corniferous	Dev			LS	Por	20±	MC			
41	Trenton	Ord	240–350	225–335	LS	Por	15±	C	Ord	967	
42	Maxon, Big Lime, shale	Mis Dev	1,800	1,425	S, L, H	Por, Cav	40± 350±	Depositional	Dev	1,816	
43	Weir, Corniferous	Mis, Dev	780–1,200	740–1,160	S, LS	Por	40±	D	Ord	3,719	
44	Weir, Big 6	Mis, Sil	700–1,100 2,100–2,500	670–1,070 2,050–2,450	S, LS	Por	30±	A	Dev		
45	Corniferous	Dev	1,670–1,760	1,650–1,740	LS	Por	18	MC	Dev	1,983	
46	Weir, Black shale, Cornif., salt sand, Maxon, Big Lime, Big Injun	Pen, Mis, Dev	1,100–1,400	1,050–1,350	S, H, L	Por, Cav	40± 450±	D-A MC-T-S	Ord	3,950	Ky. W. Va Gas Co
47		Ord	390–700	370–680	LS	Por	20±				
48	Sunnybrook-Trenton	Ord	200–500		S, LS	Por		A-D	Cambro-Ord.	1,934	
49	Salt sand	Pen			S	Por	15±	A			

the first time the rotary drill, and as a result most of the drilling in the deeper parts of the basin where the Pennsylvanian formation has a great thickness is being done with this type of drill. Probably 90 per

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[a]	To End of 1938	During 1938
50	Needmore Gas Field, *Owsley*	18		6,400		
51	Morton's Gap, *Hopkins*	18	50		*x*	*x*
52	Buford, *Ohio*	9	346		1,8*yy*,*yyy*	2*yy*,*yyy*
53	Habit, *Daviess*	8	100		23*y*,*yyy*	1*y*,*yyy*
54	Herbert, *Ohio*	18	350		440,000	15,000
55	Red Hill, *Daviess*	11	400		545,540	50,*yyy*
56	Bates Knob, *McLean*	3	370		200,*xxx*	6*y*,*yyy*
57	Hackett, *McLean*	2	150		550,*yyy*	218,*yyy*
58	Island, *McLean*	1½	150		230,*yyy*	213,*yyy*
59	Huntsville, *Butler*	1 Mo.	*x*	*x*	175	
60	Breslin, *Butler*	1 Mo.	80		100	100
61	Oklahoma, *Ohio*	7 Mos.	250		8,000	8,000
62	Rochester, *Butler*	5 Mos.	100		6,000	6,000
63	Harper, *Butler*	5 Mos.	100		2,*yyy*	2,*yyy*
64	Silver City, *Butler*	5 Mos.	150		1,500	1,500
65	Spottsville, *Henderson*	2 Mos.	60		1,260	1,260
66	Sebree, *Webster*	½ Mo.			300	300
67	Gilmore Pool, *Henderson*	5 Mos.	150		18,000	18,000
68	Birk City, *Henderson, Daviess*	8 Mos.	1,200		792,000	792,000
69	Ambrose-Weller, *Ohio*	13	600		4,126,000	25*y*,*yyy*
70	Wayne, *Wayne, McCreary*	41	8,5*xx*		4,4*yy*,*yyy*	3*y*,*yyy*
71	Logsdon Valley, Le Grande, Bonnieville, *Hart*	8	2,9*yy*		6,0*yy*,*yyy*	1*yy*,*yyy*
72	Livermore, *McLean*	3	545		1,3*yy*,*yyy*	1*yy*,*yyy*
73	Barrett Hill, *McLean*	9	250		933,815	6*y*,*yyy*
74	Owensboro, *Daviess, Ohio, McLean, Hancock, Breckenridge*	16	10,800		30,*xxx*,*xxx*	3,*xxx*,*xxx*
75	Niagara, *Henderson*	8	218		600,000	6*y*,*yyy*
76	Muhlenberg, *Muhlenberg*	9			269,224	10,*yyy*
77	Bowling Green, *Allen, Warren, Simpson*	20			12,400,000	180,*yyy*
78	Barren, *Barren*	19	3,667		2,575,029	75,*yyy*

cent of the wells drilled in the field and in the immediate surrounding area were drilled with rotary tools.

The Birk City pool covers, as present defined, approximately 1500

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					Oil-production Methods at End of 1938			Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1938
				During 1938		At End of 1938		Number of Wells				Average at End of		Gravity A.P.I. at 60° F.
	To End of 1938	During 1938	Completed to End of 1938	Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Flowing	Pumping	Miscellaneous	Initial	1937	1938	Weighted Average
50			48				3*x*				317			
51			*x*	*x*	*x*	5								
52			125	0	0	125			125	12*x*[12]				35.5
53			12	0	0	12			12					35
54			129	0	0	129	0		129			3	*y*	34
55			45	0	0	45			45			*y*	*y*	34
56	*y*	*y*	25	2	0	27	2		27		*y*	*y*	*y*	36
57			54			54			54		405	30	*y*	36.4
58			14	9		14			14					36
59			1	1		1			1		*y*			36
60			1	1		1			1		*y*			36
61			19	19		19			19		*y*			36
62			12	12		12			12		*y*			39
63			14	14	0	14	0	0	14	0	*y*		*y*	39
64			12	12	0	12	0	0	12		*y*		*y*	36
65			3	3		3		2	1		*y*		*y*	39
66			1	1		1	0		1		600			35.5
67			6	6	0	6			6		*y*		*y*	38
68			63	63	0	63			63		*y*		*y*	38
69			190	0	0	190			190	15[12]				36
70			1,4*yy*						6*yy*					
71			1,2*xx*	*x*	*x*	1,2*xx*	2*xx*		1,2*xx*					
72	30*x*		170			158			158	8[12]				34.5
73			57	0	0	57			57		320	40		35.5
74			3,*xxx*						2,*xxx*					35
75			63	*y*		63			63					34
76			20			20			20					
77			2,0*yy*			1,*yyy*			1,*yyy*					
78														

acres lying partly in Henderson County and partly in Daviess County just across Green River. The village of Birk City, 11 miles west of Owensboro and 17 miles east of Henderson, is about midway of the field,

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1938		Reference to Text[i]
	Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zones	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.	
50	Corniferous	Dev	900–1,200	850–1,150	LS	Por	40±	MC	Dev		
51	Salt sand	Pen	y	y	S	20		AF	Mis	2,132	
52	Pottsville	Pen	600	585	S	15%	15	Channel	Mis	1,250	
53	Fuqua Stray	Mis	930	910	S	18–20%	20	A	Mis	1,350	
54	Jett and Barlow	Mis	750	725	S	12	5–30	T-A	Mis	950	
55	Jett	Mis	1,015	970	S	18	14	A	Mis	1,020	
56	Pottsville, Bethel, Barlow, Bethel lime	Pen, Mis	400–1,700	340–1,670	S, L	12–15	20	AF	Mis	1,906	
57	Tar Springs, Bethel	Mis	1,150–1,450	1,100–1,500	S	20	22	A	Mis	1,525	
58	Tar Springs (Jett sand)	Mis	1,470	1,450	S		20	A	Dev	3,817	
59	Tar Springs (Jett sand)	Mis	392	377	S	y	15	T	y	y	
60	Tar Springs (Jett sand)	Mis	147	133	S	y	12	A	y	y	
61	Tar Springs (Jett sand)	Mis	615	605	S	y	10	T	y	y	
62	Tar Springs (Jett sand)	Mis	885	856	S	y	y	T	y	y	
63	Tar Springs (Jett sand)	Mis	170	150	S	y	20	T	y	y	
64	Hardinsburg (Jones sand)	Mis	506	516	S	y	10	A	y	y	
65	McClosky	Mis	2,180	2,176	OL	y	y	D	Mis	3,000	
66	McClosky	Mis	1,403	1,395	OL	y	12	A	Dev	3,217.5	
67	McClosky	Mis	2,117	2,101	OL	10–14%	10	A	Mis	2,200	
68	McClosky	Mis	1,890	1,870	OL	10–14%	10	A	Mis	2,100	
69	Tar Springs (Jett sand)	Mis	725	650–700	S	20%	40	A	Tren	4,020	
70	Beaver, Sunnybrook	Mis Ord	400–700	385–680	LS	Por	12	S	Ord	1,921	
71	Blue sand	Sil	700–850	780–1,300	L	Cav	15±	T, MC, A	Sil	x	
72	Barlow, Bethel	Mis	1,400	1,300–1,400	S	15–20%	20	AF	Dev	3,242	
73	Jett, Jackson, Barlow, Bethel	Mis	1,250	800–1,200	S	15–20%	2–75	AF	Dev	3,250	
74	Fuqua Stray, Pottsville, Jett, Jones, Barlow, Bethel	Pen Mis	400–1,300		S	18–20%	2–75	AN, A, TD	Dev	x	
75	Triplett, Jones	Pen Mis	600	580	S	Por	30±	D, A	Mis	x	
76	McClosky	Mis	1,250–1,700	1,240–1,690	L, S	Por	10±	D	Dev	x	
77	Shallow sand, Cornif., deep sand	Mis Dev			L, S	Por	15±	D, T, A MC	Ord	x	
78	2nd sand, Cornif. Amber oil sand, Trenton	Mis, Dev, Sil, Ord			L, S	Por		MC, T DN	Ord	x	

therefore there was the usual town-lot drilling and congestion. Altogether, 108 producing wells were completed up to Dec. 31 and probably 40 to 50 more will be drilled, figuring a well spacing of 10 acres to the well, the plan being carried out except in the Birk City town-lot area. In the Southern part of the field flowing wells were common and the largest wells were in this area. In the northern part of the area, the wells are smaller, although acidizing of the wells is general throughout the field. Production from the field has averaged probably 3000 bbl. daily, although proration has been in practice during its development and no attempt is made at an estimation of its peak or present production.

The structural condition in the field is that of a plunging anticline with a trend of nearly north and south. The axis, which is that of the previously mapped Curdsville anticline, rises rapidly to the north until the south edge of the field is reached, where it levels off with a gradual rise to the northern edge of the pool. The Curdsville fault lies some distance to the east, and it is possible that a parallel fault exists to the northwest of the field, although this is not definitely known at this time. Salt water is found down structure from the oil.

North and west of the Birk City field, 1½ miles south of Spottsville, the Magnolia Petroleum Co. brought about the discovery of another McClosky sand pool by the drilling of the Sam Green No. 1. This well started at 750 bbl. per day from a depth of 2176 ft. It is on the well-known and previously mapped Spottsville dome. As all the close-in acreage is held by this company, development has been slow and systematic and the limits of the field have not been defined except to the west and south.

The production for western Kentucky for the year 1938 was 3,317,191 bbl. The production at the beginning of the year was at the rate of approximately 210,000 bbl. per month, but the development of new pools, principally Birk City, as it was the only new area from which much oil was shipped to market, was responsible for an increase of nearly 150,000 bbl. per month. If a poor market and a low price for crude had not prevailed this increase would no doubt have been much larger.

In the 16 counties comprising the western Kentucky area 679 wells were completed during the year 1938. Of these 355 were oil wells, 41 gas wells and 283 dry. There were 89 wells drilling at the end of the year.

The search for and the development of gas-producing areas in western Kentucky was not intensive during the year. Market facilities are largely responsible for this condition, since it is possible to dispose of only a small portion of the production found. This does not stimulate active search for gas and practically all gas wells completed are results of wells started and drilled in search of oil.

Oil and Gas Development on the Gulf Coast of Louisiana during 1938

By Carl B. Richardson* and R. D. Sprague†

(New York Meeting, February, 1939)

The year 1938 was the most active and successful in the history of the oil industry in southern Louisiana. Drilling showed a 16 per cent increase over that of 1937, with a total of 538 wells drilled, which yielded 315 oil wells, 19 distillate wells, 4 gas wells and 200 dry holes.

Nineteen new fields were discovered during the year, all but three of which were completed by plugging back to sands previously drilled through. Electrical logging played a large part in these new discoveries as well as in the discovery of new sands during routine development of fields. Fourteen of the new discoveries produced oil, and five produced only gas and distillate.

Southern Louisiana continues to lead the world in depth of drilling, which is in part due to the great thickness of comparatively young deltaic sediments near the coast and the existence of numerous sands.

The present development is rather evenly distributed over a coastal strip 100 miles wide.

New Fields

North Tepetate, Acadia Parish.—Atlantic Refining Company's No. 1 Klumpp was completed for a new field through perforations from 7960 to 7970 ft. The initial production was 65 bbl. of 54° gravity distillate and 4 million cubic feet of gas daily through a ¼-in. choke with tubing pressure of 2850 lb. and casing pressure of 2930 lb. The well is in sec. 12, 7 S., 2 W., just north of Tepetate field. It was drilled to a depth of 8705 ft. and plugged back for its final completion. Atlantic's No. 2 was completed in a new sand at 8300 ft., also for distillate.

South Crowley, Acadia Parish.—Humble Oil and Refining Company's No. 1 Boyd Finch was completed in July 1938, as an oil well through perforations from 7318 to 7325 ft. after plugging from a total depth of 10,222 ft. After making several hundred barrels of oil, the well went to

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* Geologist, Barnsdall Oil Co., Houston, Texas.

† Geologist, Sinclair Prairie Oil Co., Houston, Texas.

salt water and was abandoned after two attempts to re-complete. The well was Humble's fourth deep test on the prospect.

Bancroft, Beauregard Parish.—One of Louisiana's most promising new fields was discovered in May 1938, by Republic Production Company's No. 1 Lutcher Moore in sec. 10, 6 S., 13 W., southwest of the town of Bancroft. The first well was completed for 55 bbl. daily of distillate through perforations from 7574 to 7579 ft., after plugging back from the total depth of 8200 ft. The second well, Republic's No. 1 Columbia Land and Timber Co., was drilled 1½ miles southwest of the distillate well, and was completed through perforations from 7321 to 7326 ft. for 630 bbl. of 41° gravity oil on a ¼-in. choke. The producing sands are in the Cockfield.

Creole, Cameron Parish.—Superior Oil Company's No. 1 State, one mile out in the Gulf of Mexico, was the discovery well for Creole field. It was completed in March 1938 for 300 bbl. daily of 42° gravity oil through perforations from 5110 to 5130 ft. Total depth before plugging back was 9394 ft. The age of the producing sand is upper Miocene.

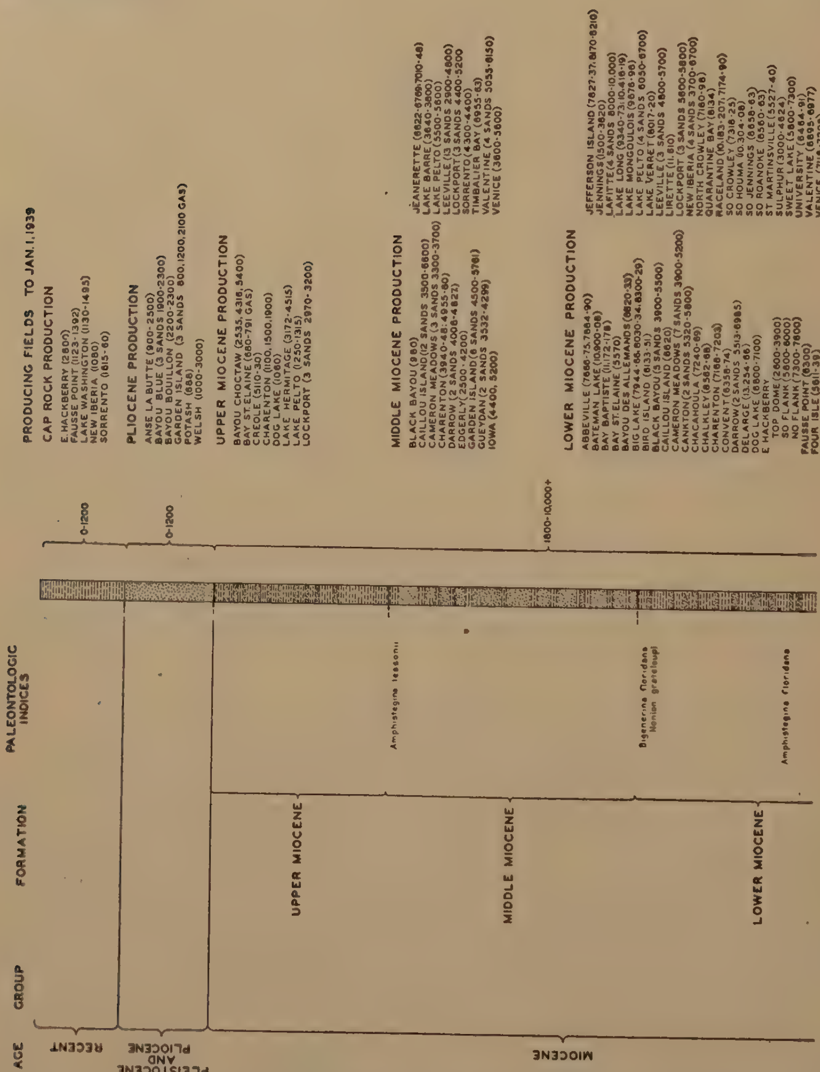
Chalkley, Cameron Parish.—Humble Oil and Refining Company's No. 2 Katherine Bel Hanszen was completed for 32 bbl. of 57° gravity distillate on a 3/16-in. choke in November 1938. Total depth of the well was 11,693 ft., and the completion is in a lower Miocene sand through perforations from 8562 to 8568 ft. Humble's No. 1 Hanszen made a small distillate well in the same sand earlier in the year but later went dead. The wells are 18 miles southeast of Lake Charles.

South Baton Rouge (University), East Baton Rouge Parish.—This field was discovered in March 1938, by Austin B. Taylor's No. 1 Duplantier, which was completed for 525 bbl. on a 3/16-in. choke with tubing pressure of 990 lb., the casing being sealed. The well was completed in 13 ft. of oil sand with a total depth of 6477 ft. It is of Miocene age.

Jefferson Island (Lake Peigneur), Iberia Parish.—The Texas Company's No. 1 Jefferson Island Salt Mining Co. was completed in June 1938 for 325 bbl. of 32° gravity oil through a 10/64-in. choke from perforations at 8170 to 8210 ft. This well was a deep flank test on a well known shallow salt dome and was drilled to a depth of 9031 ft. with the top of the salt at 8683 ft. It was then plugged back and drilled out to 8212 ft. for completion. In November, The Texas Company's No. 1 State (Lake Peigneur) was completed in another sand at 7827 to 7837 ft. for 252 bbl. of 32° gravity oil. Oil production at Jefferson Island had been established previously but wells were of only a few days duration. The discovery is significant because it is the first oil field found on one of the "Five Islands," a well-known alignment of five domes in which the salt is found at extremely shallow depths.

Woodlawn, Calcasieu Parish.—The first production in the Woodlawn field was established by Union Sulphur Company's No. 1 Calcasieu

National Bank, which was completed in February 1938 for 20 bbl. of 50° gravity oil on a ¼-in. choke through perforations from 8286 to 8288 ft. The second well, Union Sulphur Company's No. 2 Calcasieu National Bank, was completed in May for 222 bbl. daily in a deeper sand at 8895 feet.



Raceland, Lafourche Parish.—In January 1938, Amerada Petroleum Corporation brought in the discovery of Raceland field with its No. 1 South Coast Corporation. It was completed through perforations from 10,183 to 10,207 ft. for 720 bbl. of 38° gravity oil on a ¼-in. choke. Tide Water Associated Oil Company's No. 1 South Coast Corporation established production in a shallower sand at 7200 feet.

Timbalier Bay, Lafourche Parish.—Gulf Oil Corporation's No. 3 PP State (Timbalier Bay) discovered a new salt-dome oil field in January 1938 when it was completed for 304 bbl. daily on a $\frac{3}{16}$-in. choke in 60 ft. of oil sand at a depth of 6690 ft. Gravity of the oil is 32.8°. The well originally was drilled to 8728 ft., having topped the salt at 7741 feet.

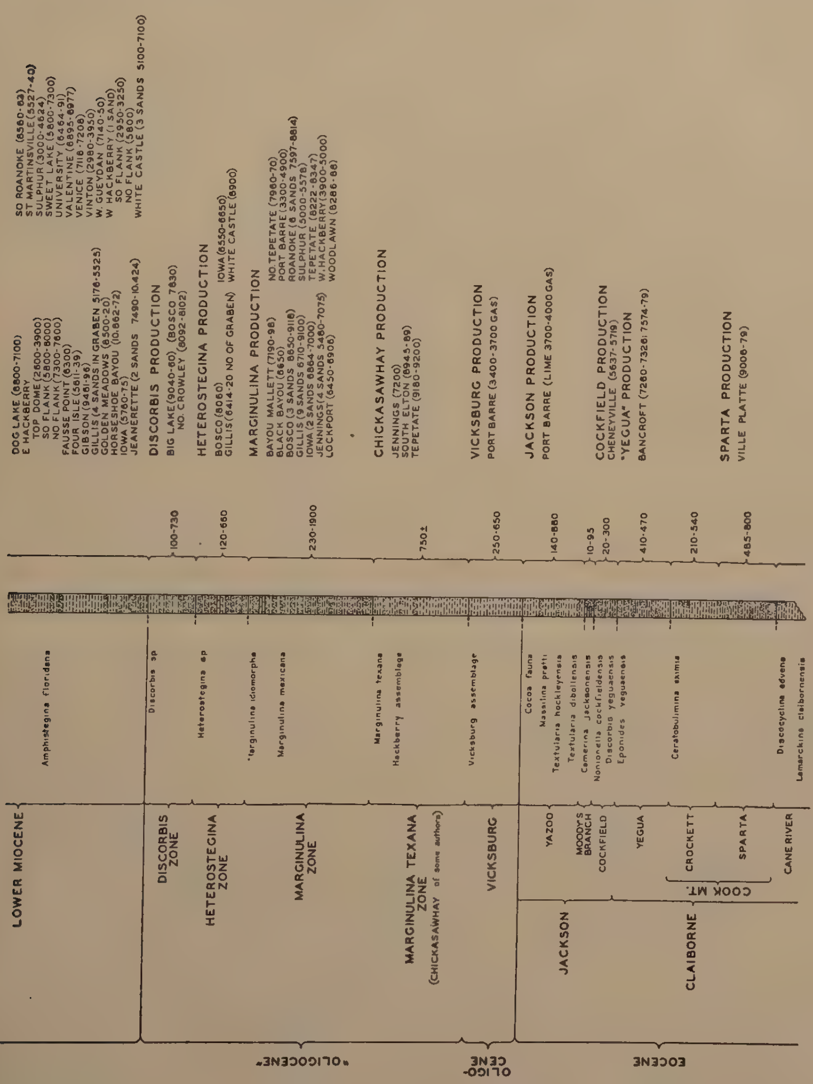


FIG. 1.—GENERALIZED GEOLOGIC COLUMN, SOUTH LOUISIANA.

Chacahoula, Lafourche Parish.—This salt dome, which was discovered in 1926, produced oil from its first deep flank test in September 1938. Sun Oil Company's No. 2 Dibert, Stark, and Brown was completed for 720 bbl. daily on a $\frac{1}{4}$-in. choke with tubing pressure of 950 lb. and casing pressure of 650 lb. The oil sand was found between 7240 and the total depth of 7253 feet.

TABLE 1.—*Oil and Gas Production in Gulf Coast of Louisiana*

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[a]	To End of 1938	During 1938
1	Abbeville, *Vermilion*	2	120	0	209,660	191,859
2	Anse La Butte, *St. Martin*	37	50	0	964,205	74,204
3	Bancroft, *Beauregard*	1	400	0	62,246	62,246
4	Bateman Lake, *St. Mary*	2	160	0	142,066	139,658
5	Bayou Blue, *Iberville*	10	20	0	85,000	13,312
6	Bayou Bouillon, *St. Martin*	23	35	0	404,074	18,841
7	Bayou Des Allemands, *St. Charles*	2	40	20	83,964	46,896
8	Bayou Mallet, *Acadia*	3	60	10	169,093	49,417
9	Bay St. Elaine, *Terrebonne*	2	80	0	136,250	84,797
10	Big Lake, *Cameron*	3	100	100	61,577	21,158
11	Black Bayou, *Cameron*	10	200	0	5,963,493	1,274,960
12	Bosco, *Acadia, St. Landry*	5	1,250	0	17,113,252	2,084,536
13	Caillou Island, *Terrebonne*	9	400	0	23,357,288	6,395,180
14	Cameron Meadows, *Cameron*	8	190	0	6,207,154	1,280,154
15	Cankton, *St. Landry*	3	20	0	22,802	10,553
16	Chacahoula, *Lafourche*	1	50	0	60,270	60,270
17	Chalkley, *Cameron*	1	200	0	671	671
18	Charenton, *St. Mary*	3	330	0	1,306,900	1,065,700
19	Cheneyville, *Rapides*	4	160	0	429,099	157,113
20	Choctaw, *Iberville*	8	120	0	2,221,621	491,282
21	Convent, *St. James*	1	20	0	16,398	16,398
22	Creole, *Cameron*	1	100	0	156,442	156,442
23	Crowley, North, *Acadia*	2	250	0	392,868	361,718
24	Crowley, South, *Acadia*	1	20	0	240	240
25	Darrow, *Ascension*	7	120	0	2,534,000	1,014,800
26	Dulac, West, *Terrebonne*	1	*x*	*x*	13,955	13,955
27	Dog Lake, *Terrebonne*	10	50	0	1,622,432	522,898
28	Edgerly, *Calcasieu*	27	215	0	8,497,271	59,156
29	Elton, South, *Jefferson Davis*	2	20	0	10,764	8,765
30	Fausse Point, *Iberia*	12	20	0	37,133	4,296
31	Four Isle, *Terrebonne*	5	20	0	94,177	1,307
32	Garden Island, *Plaquemines*	4	250	0	1,811,037	841,636
33	Gibson, *Terrebonne*	2	260	0	1,409,364	990,721
34	Gillis, *Calcasieu*	5	1,920	0	16,073,081	3,163,284
35	Golden Meadows, *Lafourche*	1	40	0	2,294	2,294
36	Grand Bay, *Plaquemines*	1	60	0	49,571	49,571
37	Gueydan, *Vermilion*	7	25	0	882,113	160,860
38	Gueydan, West, *Vermilion*	1	40	0	29,472	29,472
39	Hackberry, *Cameron*	11	200	0	5,097,209	1,269,088
40	Hackberry, East, *Cameron*	11	500	0	19,098,012	2,404,165
41	Horseshoe Bayou, *St. Mary*	2	80	0	302,561	227,890
42	Houma, *Terrebonne*	27	0	720		

[a] Footnotes to column heads and explanation of symbols are given on page240.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					Oil-production Methods at End of 1938			Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1938
				During 1938		At End of 1938		Number of Wells				Average at End of		Gravity A.P.I. at 60° F.
	To End of 1938	During 1938	Completed to End of 1938	Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Flowing	Pumping	Gas Lift	Initial	1937	1938	Weighted Average
1	y	y	5	3	0	5	0	3	0	0	2,800	2,700	2,500	42
2			41	3	3	9		0	9					
3			6	6	0	5	1	5	0		600–2,600			44
4			1	0	0	1	0	1	0					33
5	x	x	7	0	0	1	0	1	0	0	650	650	400	19
6			11	0		2		0	2					25
7	x	x	3	2	0	2	1	3	0	0	700–2,100		300–2,100	
8			5	0		y		y	y					y
9			3	1		2	0	y	y					29
10	x	x	3	5	2	3	1	2	0					55
11			32	4	0	19		12	7					y
12			69	0	0	53		53	0					y
13			39	2		38		y	y					y
14	x	x	47	11	1	36	0	21	11	y				37
15			2	0		1		1	0					y
16			2	2	0	2		2	0					33
17			1	1	0	1		1	0		1,400–3,000			57
18	y	y	42	35	0	38	0	12	16	10	Normal	y	y	y
19	y	y	8	2		5	0	5	0	0	{1,200 1,800}	y	{700 1,600}	y
20			15	3	0	10		3	7					
21	x	x	1	1	0	1	0	1	0	0	2,400		2,200	43
22			3	3	0	3		3	0		600–2,150			34
23	x	x	11	8	0	11	0	11	0	0	1,450	1,450	1,450	36
24			1	1		0		0	0		5,100–7,500			35
25	x	x	19	6		9	0	8	1	0	400–1,350	x	350–1,300	37
26	537	537	1	1	0	1	0	1	0	0	4,800		4,730	51
27			26	3	1	5		4	1					39
28			177	0	2	12		3	11					20
29			1	0		1		1	0					52
30			6	1	0	1		1	0					37
31			2	0		1		1	0					44
32			14	6	1	8		y	y					y
33			13	6	0	13		13	0					37
34	x	x	75	5	1	83	0	y	y					34
35			1	1	0	1		1	0					y
36			3	3	0	3		3	0		2,450			27
37			5	0	0	5	0	3	2	0				27
38			1	1	0	1		1	0		y			62
39			98	15		57		11	46					23
40			132	6		50		17	33					y
41			2	1	0	2		2	0					40
42			10			0	y							

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1938	
	Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
1	Brookshire sand	Mio	7,900	7,860	S	Por	30	D	Oligocene	12,214
2	Pli, Mio	Pli, Mio	Several sands 400–1,890		S	Por	35	DS	Miocene	6,204
3	Cockfield	Eoc	7,361	7,260	S	Por	100	D	Cockfield-Yegua	8,091
4	Mio	Mio	10,530 10,905	10,517 10,900	S	Por	10	D	Miocene	11,879
5	Pli	Pli	1,720	1,710	S	Por	10	DS	Vicksburg	8,090
6	Mio	Mio	Several sands 535–4,795		S	Por	30	DS	Vicksburg	6,471
7	Mio	Mio	6,830 7,254 9,463	6,820 7,239 9,380	S	Por	15 25 50	DS	Salt & Miocene?	9,914
8	Marg	Mio-Olig	3 sands 6,386–7,198		S	Por	20	D	Vicksburg	8,404
9	Mio	Mio	5,643	5,520 6,834	S	Por	60	DS	Miocene	6,831
10	Mio	Mio	8,334 7,944	8,318 7,966	S	Por	20	D	Heterostegina	10,521
11	Cap, Mio, Marg	Mio	Several sands 2,030–5,473		L, S	Por	110	DS	Marginulina?	6,905
12	Disc, Het, Marg	Mio	Several sands 7,830–9,118		S	Por	90	D	Vicksburg	10,432
13	Mio	Mio	Several sands 4,510–6,813		S	Por	90	DS	Miocene	6,813
14	Mio	Mio	4,113	4,080	S	Por	40	DS	Miocene	9,331
15	Mio	Mio	5,323	5,315	S	Por	10	D	Frio	9,428
16	Mio	Mio	7,253	7,240	S	Por	20	DS	Miocene	7,253
17	Mio	Mio	8,568	8,562	S	Por	10	*x*	Miocene	11,693
18	Mio	Mio	Several sands 1,100–7,200		S	Por	30	DS	Miocene	10,317
19	Cockfield sparta	Eoc	5,740 6,000	5,732 5,990	S	Por	15 15	DS	Wilcox	8,565
20	Mio	Mio	3,107 8,259	3,052 8,250	S	Por	45	DS		8,969
21	Mio	Mio	6,364	6,358	S	Por	65	DS	Oligocene	9,525
22	Mio	Mio	5,120	5,110	S	Por	55	D	Miocene	9,394
23	Mio, Discorbis, Het, Marg, Frio	Mio Mio-Olig	7,200 8,600	7,190 8,580	S	Por	15	D	Frio	10,632
24	Mio	Mio	7,325	7,318	S	Por	7	D	Marginulina	10,272
25	Mio	Mio	5,650 7,050	5,500 6,850	S	Por	34	DS	Vicksburg	7,904
26	Mio	Mio	13,333	13,208	S	Por	77	AF	Miocene	13,333
27	Mio	Mio	Several sands 3,206–6,842		S	Por	15	DS	Miocene	7,174
28	Pli, Mio	Pli, Mio	Several sands 410–4,341		S	Por	130	DS	Jackson	8,414
29	Chickasawhay (Alazan	Olig	8,965	8,955	S	Por	25	D	Cockfield-Yegua	13,210
30	Mio	Mio	Several sands 3,150–8,000		S	Por	7	DS	Miocene	7,157
31			5,642	5,512			50	DS	Miocene	10,725
32	Mio	Mio	Several sands 4,072–6,993		S	Por	15	DS	Miocene	7,200
33	Mio	Mio	8,887 9,518	8,880 9,460	S	Por	40	D	Miocene	10,727
34	L Mio, Het, Marg	Mio, Mio-Olig	9,246	5,156	S	Por	15	D	Marginulina	9,246
35	Mio	Mio	8,510	8,500	S	Por	10	D	Miocene	11,135
36	Mio	Mio	6,151	6,132	S	Por	20	D	Miocene	7,141
37	Mio	Mio	Several sands 3,500–4,300		S	Por	40	DS	U Oligocene	9,545
38	Mio	Mio	7,150	7,140	S	Por	10	*x*	Miocene	9,865
39	Mio, Marg	Mio	Several sands 1,056–7,125		S	Por	35	DS	Vicksburg	7,834
40	Mio	Mio	Several sands 1,710–7,664		S	Por	65	DS	Vicksburg	8,525
41	Mio	Mio	10,873	10,863	S	Por	40	D	Miocene	12,261
42	Mio	Mio	Several sands 1,000–6,937		S	Por	10	D	Miocene	5,645

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[a]	To End of 1938	During 1938
43	Houma, South, *Terrebonne*	1	40	0	15,957	15,957
44	Iowa, *Calcasieu, Jefferson Davis*	8	720	0	35,048,846	5,643,317
45	Jeanerette, *St. Mary*	4	400	0	5,774,901	2,506,147
46	Jefferson Island, *Iberia*	1	20	0	21,229	21,229
47	Jennings, *Acadia*	38	480	0	62,748,264	7,469,709
48	Jennings, South, *Jefferson Davis*	3	160	0	9,351	6,580
49	Lafitte, *Jefferson*	4	2,400	0	13,459,100	5,951,591
50	Lake Barre, *Terrebonne*	10	340	0	15,770,674	671,985
51	Lake Hermitage, *Plaquemines*	5	25	0	119,851	10,417
52	Lake Long, *Lafourche*	2	2,500	0	358,983	275,369
53	Lake Pelto, *Terrebonne*	10	80	0	993,570	423,544
54	Lake Verrett, *St. Martin*	1	40	0	4,788	4,788
55	Lake Washington, *Plaquemines*	8	160	0	2,415,000	335,094
56	Leeville, *Lafourche*	8	480	0	18,987,503	1,863,035
57	Lirette, *Terrebonne*	2	400	0	34,000	7,465
58	Lockport, *Calcasieu*	15	500	*x*	14,566,330	378,038
59	New Iberia, *Iberia*	22	250	0	13,990,664	5,347,124
60	Pine Prairie, *Evangeline*	27	10	0	20,000	0
61	Port Barre, *St. Landry*	10	300	0	7,474,000	621,000
62	Potash, *Plaquemines*	2	100	0	463	433
63	Quarantine Bay, *Plaquemines*	2	40	0	264,304	263,333
64	Raceland, *Lafourche*	1	100	20	250,888	256,742
65	Roanoke, *Jefferson Davis*	5	900	0	7,263,000	1,280,872
66	Roanoke, South, *Jefferson Davis*	2	40	0	45,413	41,283
67	St. Martinsville, *St. Martin*	4	35	0	798,388	252,952
68	Sorrento, *Ascension*	11	100	0	897,700	110,900
69	Starks, *Calcasieu*	14	160	0	2,636,089	204,376
70	Sulphur, *Calcasieu*	13	150	0	12,519,436	1,230,537
71	Sweet Lake, *Cameron*	13	300	0	3,880,804	309,651
72	Tepetate, *Acadia*	4	1,200	0	5,619,852	1,979,170
73	Tepetate, North, *Acadia*	1	320	0	6,683	6,683
74	Timbalier Bay, *Lafourche*	1	20	0	35,558	35,558
75	University, *E. Baton Rouge*	1	300	0	165,620	165,620
76	Valentine, *Lafourche*	3	150	0	2,630,000	1,670,000
77	Venice, *Plaquemines*	2	*y*	0	650,281	501,475
78	Ville Platte, *Evangeline*	2	1,000	0	803,340	797,153
79	Vinton, *Calcasieu*	29	270	0	43,018,932	471,651
80	Welch, *Jefferson Davis*	36	50	0	628,865	10,070
81	White Castle, *Iberville*	10	150	0	2,862,326	592,037
82	Woodlawn, *Jefferson Davis*	1	80	0	177,053	177,053

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft. — To End of 1938	Total Gas Production, Millions Cu. Ft. — During 1938	Number of Oil and/or Gas Wells — Completed to End of 1938	Number of Oil and/or Gas Wells — During 1938 — Completed	Number of Oil and/or Gas Wells — During 1938 — Abandoned	Number of Oil and/or Gas Wells — At End of 1938 — Producing Oil[b]	Number of Oil and/or Gas Wells — At End of 1938 — Producing Gas[c]	Oil-production Methods at End of 1938 — Number of Wells — Flowing	Oil-production Methods at End of 1938 — Number of Wells — Pumping	Oil-production Methods at End of 1938 — Number of Wells — Gas Lift	Pressure, Lb. per Sq. In.[d] — Initial	Pressure, Lb. per Sq. In.[d] — Average at End of 1937	Pressure, Lb. per Sq. In.[d] — Average at End of 1938	Character of Oil, Approx. Average during 1938 — Gravity A.P.I. at 60° F. — Weighted Average
43			1	1	0	1		1	0		*y*			37
44	*x*	*x*	81	1	4	71	0	47	10					41
45			23	1		23		22	1					*y*
46			2	2	0	2		2	0					37
47			624	50	*y*	133	*y*	72	60					*y*
48			1	0	0	2		2	0					*y*
49			28	11	0	27		*y*	*y*					*y*
50			44	1		26		*y*	*y*					*y*
51			3	0	0	2	0	70	2					*y*
52	1,899	1,697	5	4	0	5	0	5	0	0	2,875		2,850	39.8
53			10	2	1	6		*y*	*y*					*y*
54			1	1	0	1		1	0		1,000			*y*
55	*x*	*x*	13	0	0	7	0	7	0	0	150		125	18.3
56			126	3		91		14	77					*y*
57	*x*	*x*	3	2	0	1	2	1	0	0	3,200		3,200	45
58	*x*	*x*	89	1		22	1	5	13					33
59			65	23		48		34	14					*y*
60			4			0		0	0					*y*
61	*y*	*y*	37	5	*y*	32	0	2	30	0	*y*	*y*	*y*	*y*
62	*x*	*x*	1	0	0	0	0	0	0	0	250		*x*	18
63			5	4	0	4		4	0					36
64	0		3	3		3	0	3	0	0	2,000		2,000	*y*
65	*x*	*x*	39	3	1	25	2	25	0	0	1,350	*y*	1,100	38
66			2	0	0	2		2	0					47
67	277	88	2	0	0	2	0	2	0	0	*y*	*y*	*y*	31.5
68	*y*	*y*	14	4	0	8	1	5	3	0	*y*	*y*	*y*	*y*
69			32	2		20		1	19					
70			119	8		62		6	56					
71			11	2	0	6	0	8	0		*y*	*y*	*y*	29
72	*y*	*y*	58	0	1	53	0	53	0	0	3,000	2,600	2,400	36
73			2	2	0	2		2	0		2,930–3,100			54
74			1	1	0	0		0	0		800			33
75			6	6		6		6	0		*y*			32
76	*y*	*y*	23	8	0	23	0	21	0	2	*y*	*y*	*y*	*y*
77	436	336	6	4	2	5	0	5	0	0	*y*	*y*	*y*	41
78	*y*	*y*	36	35	0	34	0	34	0	0	2,600	2,600	2,100	40
79			444	0	2	70		0	70					29.4
80			67	0	5	13		0	13					23
81			13	3	1	7		4	3					*y*
82			4	3	0	4		3	1		740–2,130			*y*

TABLE 1.—(*Continued*)

Line Number	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
43	Mio	Mio	10,308	10,305	S	Por	10	x	Miocene	11,047
44	U Mio, Heterostegina, Marg	Mio, Mio-Olig	6,941	6,920	S	Por	53	D	Vicksburg	9,161
45	Mio	Mio	Several sands 6,609–10,424		S	Por	50	D	Miocene	11,634
46	Mio	Mio	7,837 8,210	7,827 8,170	S	Por	40	DS	Miocene	9,031
47	U Mio to Marginulina	Mio	Many sands 1,883–7,600		S	Por	120	DS	Vicksburg	9,132
48	Mio	Mio	8,648	8,634	S	Por	20	D	Heterostegina	9,944
49	Mio	Mio	3 sands 8,035–10,130		S	Por	80	D	Miocene	12,128
50	Mio	Mio	3,836	3,777	S	Por	75	DS	Miocene	11,333
51	Mio	Mio	Several sands 3,172–4,646		S	Por	15	DS	Miocene	9,770
52	Mio	Mio	7 sands 9,360–10,430		S	Por	y	D	Miocene	11,347
53	Mio	Mio	1,373 6,270	1,274 6,248	S	Por	55	DS	Miocene	7,344
54	Mio	Mio	8,032	8,017	S	Por	10	D	Heterostegina	
55	Cap rock	Pli	1,150	1,140	L	Por	10	DS	Miocene	6,473
56	Mio	Mio	Many sands from 2,929–6,530		S	Por	120	DS	Miocene	8,994
57	Fleming	Mio	8,460 10,525	8,420 10,520	S	Por	10	D	Miocene	13,409
58	U Mio, Marg	Mio	4,558	4,533	S	Por	100	D	Marginulina	7,902
59	Pli, Mio	Pli, Mio	Several sands 2,760–6,159		S	Por	50	DS	Miocene	9,210
60	Mio	Mio	Several sands 1,008–5,410		S	Por	30	DS	Eocene	5,917
61	Mio, Olig	Mio	3,190 4,950		S	Por	25	DS	Frio	7,213
62	Pli	Pli	695	689	S	Por	10	DS	Miocene	10,027
63	Mio	Mio	8,186	8,120	S	Por	45	D	Miocene	11,014
64	Mio	Mio	10,132	10,208	S	Por	80	D	Miocene	12,200
65	Heterostegina, Marg, Frio	Mio-Olig	7,850 8,850	7,800 8,800	S	Por	15	D	Vicksburg	10,750
66	Mio	Mio	8,563	8,540	S	Por	25	D	Marginulina	12,088
67	Smedes sand	Mio	5,562 5,582	5,525 5,540	S	Por	y	D	Oligocene?	9,646
68	Mio-Olig, Mio and Cap	Mio	Several sands 900–4,378		A, S	Por	20	DS	Vicksburg	6,565
69	Pli, Mio, Cap	Pli, Mio	Several sands 800–4,300		S	Por	40	DS	Jackson	7,207
70	U Mio, Marg	Mio	Several sands 2,610–7,675		S	Por	100	DS	Vicksburg	9,250
71	Mio	Mio	Several sands 5,650–7,396		S	Por	25	DS	U Oligocene	8,928
72	Ortego sand	Mio-Olig	8,320	8,300	S	Por	28	D	Marginulina	9,447
73	Marg-Frio	Mio-Olig	7,970 8,504	7,960	S	Por	20	x	Vicksburg	8,705
74	Mio	Mio	6,963	6,955	S	Por	10	DS	Miocene	8,728
75	Mio	Mio	6,490	6,460	S	Por	30	D	Vicksburg	10,360
76	Mio	Mio	Several sands 3,700–9,325		S	Por	40	DS	Miocene	10,055
77	Mio	Mio	7,200 5,700 3,650	7,150 5,600 3,600	S	Por	40 50 25	DS	Miocene	7,719
78	Sparta	Eoc	9,050	8,910	S	Por	60	D	Wilcox	10,507
79	Pli, Mio		Several sands 1,060–4,055		S	Por	90	DS	Vicksburg	6,939
80	Pli	Pli	Several sands 1,100–3,665		S	Por	10	D	Vicksburg	9,010
81	Mio	Mio	Several sands 1,274–6,540		S	Por	33	DS	Oligocene	9,127
82	Marg	Mio-Olig	8,288 8,898	8,286 8,894	S	Por	15	D	Vicksburg	9,552

Grand Bay (Bird Island), Plaquemines Parish.—Gulf Oil Corporation's No. 1-A Grand Prairie Levee District was completed as the discovery well of the new field in July 1938, in a sand from 6133 to 6151 ft. The initial production was 375 bbl. of 28° gravity oil on 3/8-in. and 1/4-in. chokes. It is in sec. 6, T. 20 S., R. 19 E.

Convent (Hester), St. James Parish.—This previously discovered salt dome became a producing field in July 1938, with the completion of Continental Oil Company's No. 1 Realty Operators on the north bank of the Mississippi River in sec. 16, T.12 S., R.5 E. The well was drilled to a total depth of 7479 ft. and completed through perforations at 6358 to 6374 ft. The initial production was 70 bbl. of 64° gravity distillate.

TABLE 2.—*Summary of Drilling Operations in Gulf Coast of Louisiana*

Important Wildcats Drilled in 1938

	Parish	Location			Total Depth, Ft.	Deepest Horizon Tested
		Sec.	Twp.	Rge.		
1	Acadia, North Tepetate	12	7S	2W	8,705	Alazan
2	Acadia, Jennings	46	9S	2W	6,972	Marginulina
3	Acadia, North Crowley	34	8S	1E	7,985	Heterostegina
4	Avoyelles, Wildcat	7	2S	4E	9,014	Wilcox
5	Beauregard, Bancroft	10	6S	13W	8,200	Cockfield
6	Beauregard, Bancroft	16	6S	13W	7,395	Cockfield
7	Cameron, Chalkley	9	12S	6W	11,693	Miocene
8	Cameron, Wildcat	7	14S	6W	10.895	Miocene
9	Cameron, Creole	South of 4	15S	8W	9,394	Miocene
10	Cameron, East Hackberry	37	12S	10W	7,097	Marginulina
11	Cameron, Hackberry	30	12S	10W	6,913	Marginulina
12	East Baton Rouge, S. Baton Rouge	65	7S	1W	6,477	Miocene
13	Iberia, Jefferson Island	58	12S	5E	9,031	Salt
14	Iberia, Wildcat	Vermilion Bay			9,667	Miocene & Salt
15	Jefferson Davis, South Roanoke	36	10S	4W	12,088	Marginulina
16	Jefferson Davis, South Elton	27	7S	3W	13,210	Yegua
17	Jefferson Davis, Woodlawn	12	9S	8W	8,524	Marginulina
18	Lafayette, Wildcat	36	9S	9E	10,973	Marginulina
19	Lafourche, Timbalier Bay	35	23S	21E	8,728	Salt
20	Lafourche, Raceland	34	15S	19E	10,301	Miocene
21	Lafourche, Chacahoula	70	15S	15E	7,253	Miocene
22	Lafourche, Golden Meadows	1	20S	21E	11,135	Miocene
23	Lafourche, Valentine	3	17S	20E		Alazan?
24	Lafourche, Valentine	58	17S	20E	10,055	Alazan?
25	Plaquemines, Grand Bay	6	20S	19E	6,151	Miocene
26	Plaquemines, Venice	23	21S	30E	7,472	Miocene
27	Pointe Coupee, Wildcat	28	3S	8E	9,893	Wilcox
28	Rapides, Cheneyville	53	1S	2E	7,045	Salt
29	Plaquemines, Garden Island Bay	38	23S	33E	6,993	Miocene
30	St. James, Convent	16	12S	5E	7,499	Miocene
31	St. John the Baptist, Wildcat	97	11S	17E	11,005	
32	St. Landry, Wildcat	60	4S	4E	11,220	Wilcox
33	St. Martin, Lake Verret	15	14S	12E	9,835	Miocene
34	St. Martin, Lake Mongouloi	10	10S	9E	10,403	Salt
35	Terrebonne, West Dulac	77	19S	17E	13,333	Miocene
36	Terrebonne, Bay Baptiste	41	19S	19E	13,409	Miocene
37	Terrebonne, South Houma	73	18S	18E	11,047	Miocene
38	Terrebonne, Wildcat	10	18S	16E	11,208	Miocene
39	Terrebonne, Raccoon Point	Caillou Bay			4,970	Salt
40	Terrebonne, Gibson	40	17S	15E	10,752	Miocene
41	Terrebonne, Lake Barre	40	21S	20E	11,333	Miocene & Salt
42	Vermilion, West Gueydan	5	12S	2W	9,146	Miocene
43	Terrebonne, Caillou Island	19	23S	20E	6,813	Miocene

Lake Verret, St. Martin Parish.—Shell Petroleum Corporation's No. 1 Hazel Burdin, the third deep test for the large Lake Verret structure, was successfully completed for a new field in December 1938. The well had been drilled to a depth of 9833 ft., and was plugged back to 8049 ft. for completion through perforations from 8017 to 8032 ft. The initial production was 129 bbl. of oil and 110 bbl. of salt water daily on $^{12}/_{64}$-in. and $^{14}/_{64}$-in. chokes. The discovery is in sec. 15, T.14 S., R.12 E.

Lake Mongoulois, St. Martin Parish.—The Texas Company's No. 6 State (Lake Mongoulois) brought in the first production on this prospect, upon which five wells had been drilled previously. It made 59 bbl. of distillate in 12 hr. on a $^{14}/_{64}$-in. choke through perforations from 9675 to 9695 ft. The total depth of the well had been 10,403 ft. in salt, which

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	Operator, Farm, and Number	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Atlantic-C. R. Klumpp No. 1	65	4	1/4	2,930	2,850	New distillate field
2	Superior-Clement No. 1	431		14/64	1,125	1,310	New sand & extension
3	Humble-Fed. Land Bk. No. 2	768		1/4	750	1,025	New sand
4	Magnolia-Bowden No. 1						Dry hole
5	Republic-Lutcher Moore No. 1	50	5		250	2,250	First distillate well
6	Republic-Columbia Land No. 1	630		1/4	2,600	1,600	First oil well
7	Humble-Hanszen No. 2	32	2.6	3/16	Sealed	3,000	Distillate discovery
8	Humble-Miami Corp. No. B-1						Dry hole
9	Superior-State No. 1	215		1/4		800	New field in Gulf of Mexico
10	Union Sulphur-Doiron No. 9	1,221?		3/16?	2,275	3,600	New sand
11	Superior-Vincent No. 1	18	1.8	12/64		2,350	New sand
12	Taylor-Duplantier No. 1	525	0.5	3/16	Sealed	990	New field
13	Texas Co.-Salt Mine No. 1	325		10/64		1,590	New field
14	Texas Co.-State No. B-2						Important gas blowout
15	Continental-Sturdivant No. 1	84	1	5/32	750	5,200	Completed at 9865
16	Stanolind, Amerada-Nat'l Bank No. B-3						No sand in Cockfield
17	Union Sulphur, Magnolia-Nat'l Bank No. 1	48	2.3	12/64		1,000	New field
18	Continental-Foreman No. 1						Dry hole
19	Gulf-State No. 3 "PP"	304		3/16	800	750	New discovery
20	Amerada-South Coast No. 1	720		1/4	1,200	1,575	New discovery
21	Sun-Dibert, Stark, & Brown No. 2	720		1/4	650	950	New discovery
22	Texas Co.-La Terre Land No. 1	162		3/16		2,700	New discovery
23	William Helis-Valentine No. 2	102		1/4	400	1,100	New sand
24	Pan. Am. & Barnsdall-Community No. B-2	360		3/16		1,750	New deep sand
25	Gulf-Grand Prairie No. A-1	375		3/8 & 1/4	250	470	New field
26	Tidewater-Buras Levee No. 1	1,180			Sealed	600	New sand at 5600
27	Scranton-Hackney Lbr. No. 1						Dry hole
28	Amerada-Weil No. 4	492		Various	1,000	775	First well to salt
29	Texas Co.-State No. 29	962		1/4		1,790	New deep sand at 6900
30	Continental-Realty Operators	128	4.2	23/64		2,450	New distillate field
31	Shell-Godchaux Sugars No. 1						Dry hole
32	Herton-Thistlewaite No. 1						Dry hole
33	Shell-Hazel Burdin No. 1	283		1/4	1,350	750	New discovery
34	Texas Co.-State No. 6	59	4	1/4		3,300	New distillate field
35	Fohs-Buckley Bourg No. 1	125	3	1/4			New distillate field
36	Fohs & Shell-Bay Baptiste No. 1	55	0.3	10/64			New distillate field
37	Shell-Peters No. 1	450		1/4	3,750	3,295	New field
38	Shell & Barnsdall-Realty Operators No. 1-c						Dry hole
39	Texas Co.-State No. 1						Dry hole, new salt dome
40	Shell-Kuntz No. 1	200		1/4			New upper sand and extension
41	Texas-State No. 42	20		1/4		2,375	Top of salt 11,301, deepest ever drilled
42	Magnolia-J. B. Ferguson No. 1	85		1/4	2,500	2,600	New distillate field
43	Texas-Terrebonne Bay No. 1	418		1/4		2,075	New deep sand

was encountered at 10,388 ft. The No. 6 well is the northernmost of the six tests, and is in sec. 10, T.10 S., R.9 E.

West Dulac (De Large), Terrebonne Parish.—Fohs Oil Co. completed its No. 1 Buckley Bourg in June 1938 for the world's deepest producing well at that time. It came in for 125 bbl. of 47° gravity oil through a ¼-in. choke through perforations at 13,254 to 13,266 ft. The well was drilled to a depth of 13,333 ft., at which point it was still in lower Miocene. It is in sec. 77, T.9 S., R.17 E.

Bay Baptiste, Terrebonne Parish.—Fohs Oil Co. and Shell Petroleum Corporation's No. 1 State (Bay Baptiste) was drilled to a new depth record for Louisiana, 13,409 ft., before it was completed through perforations at 11,172 to 11,178 ft. in August 1938. The initial production was 55 bbl. of distillate and 250,000 cu. ft. of gas through a $^{10}/_{64}$-in. choke. The well is in sec. 41, T.19 S., R.19 E.

South Houma, Terrebonne Parish.—Shell Petroleum Corporation's No. 1 Peters, in sec. 73, T.18 S., R.18 E., was completed in November 1938 for 450 bbl. of 37° gravity oil. The well had been drilled to a depth of 11,047 ft., and plugged back and perforated at 10,305 to 10,308 ft. The production is from a lower Miocene sand.

West Gueydan, Vermilion Parish.—Magnolia Petroleum Corporation's No. 1 J. B. Ferguson brought in a new field when it was completed for 75 bbl. daily in 10 ft. of oil sand topped at 7145 ft. The well had been drilled to a depth of 9116 ft. before plugging back.

New Salt Dome

Raccoon Point (Caillou Bay) salt dome, Terrebonne Parish, was discovered in August 1938 by The Texas Company's No. 1 State, which encountered salt at 4922 ft. It was the first well drilled on an old geophysical prospect in the Gulf of Mexico about one mile west of Raccoon Point, which is the western extremity of Isle Derniere. Several shows of oil were encountered, but the well was abandoned after encountering salt. At the end of the year, preparations were being made for a second well by The Texas Company.

Blowout at Vermilion Bay

The Texas Company's No. 2-B State on the flank of Vermilion Bay dome in Iberia Parish had a serious blowout while at a depth of 9667 ft., as plugs were being drilled from 5¾-in. casing. The well blew about 100 million cu. ft. of gas daily before it was capped. It is significant because it lies almost 25 miles distant from oil or gas production and because such large accumulations of gas are unusual on the flanks of shallow piercement domes.

New Sands

During 1938 many new oil sands were discovered in southern Louisiana fields. This is to be expected in the drilling of faulted structures and salt domes in a series of interbedded sands and shales. Some of the more important new sands from a standpoint of reserves were the Clement sand at Jennings, three shallow sands and a deep sand at Charenton, the 8600-ft. Miocene sand at North Crowley, the 8050-ft. sand at LaFitte, two shallower sands at Venice, and the Hayes sand on the north flank of Ville Platte.

New sands were also discovered and brought into production at Jeanerette, Leeville, Lake Long, Valentine, East Hackberry, Lake Barre, Raceland, Port Barre, Sorrento, Gibson, New Iberia, Bayou des Allemands, Choctaw, South Roanoke, West Hackberry, Bay Sainte Elaine, Tepetate, and Cheneyville.

Eola Field, January 1939

The discovery of Eola field, in Avoyelles Parish, as coastal Louisiana's first field for 1939 has created as much interest as any on the Gulf Coast during the past 10 years because it arouses interest in the Wilcox trend. The discovery well, S. W. Richardson's No. 1 Haas, was completed in the Wilcox sand at 8443 to 8550 ft., the entire thickness drilled being perforated with 672 shots. Initial production based upon a 45-min. test was reported at 700 bbl. daily on a ¼-in. choke. Later it was gauged at 225 bbl. daily on a ⅛-in. choke with pressures of about 1600 pounds.

The field is believed to be of major importance in itself in addition to having a pronounced effect upon exploration and leasing during 1939.

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Oil and Gas Development in North Louisiana in 1938

By H. K. Shearer,* Member A.I.M.E.

Oil production in north Louisiana in 1938 was 28,442,910 bbl., a decrease of 225,160 bbl., or less than 1 per cent, from 1937. The principal increases were at Cotton Valley, Lisbon and Zwolle. The greatest decrease was at Rodessa, with small normal declines in production of the old settled fields.

Natural gas production from gas wells declined 15.9 per cent from 1937, but casinghead gas increased, so the decline in total production was only 6.9 per cent.

Well completions in 1937 and 1938 were as follows:

Year	Oil	Gas	Dry	Total	Wildcat Producers	Wildcat Dry Holes
1937	411	175	130	716	7	58
1938	350	117	141	608	2	47

Decline in completions was due to lack of proven areas for drilling, as well as price and marketing difficulties; and wildcat activity was also less than in 1937. The increase in number of dry holes was due chiefly to shallow drilling in the old Caddo and Zwolle fields.

Most important events in 1938 were the discovery of the Shreveport deep oil and gas field, extension of the Logansport gas-distillate field into Louisiana, development of oil production in the Bodcaw zone on the flanks of Cotton Valley, opening of deep gas-distillate production at Shongaloo, and completion of one well in a deeper horizon at Blue Lake (Zwolle field).

Geological Notes

The deep drilling done in 1938 did not cause any important changes in geological correlation and nomenclature of the formations below the Upper or Gulf Cretaceous. The stratigraphic section of the Lower Cretaceous and deeper beds, with names used in the accompanying tables, as approved a year ago by the Shreveport Geological Society, is as follows:

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* Geologist, The Hunter Company, Inc., Shreveport, La.

Lower Cretaceous
- Washita group
- Fredericksburg group
- Trinity group
  - Paluxy—red beds, sand, shale, limestone
  - Upper Glen Rose—shale, limestone
  - Middle Glen Rose—anhydrite, shale, limestone
  - Lower Glen Rose
    - Rodessa member—limestone, sand, shale
    - Pine Island member—shale, limestone
  - Travis Peak—red beds, sand, shale

Lower Mesozoic ?
- Cotton Valley—marine shale, sand, limestone
- Buckner—anhydrite, shale, dolomite
- Smackover—limestone with Reynolds oolite near top
- Rock salt / Eagle Mills—red beds, sand, shale

Paleozoic—shale, sandstone, igneous rock

Four tests in north Louisiana were drilled to depths of more than 10,000 ft., and two others more than 9000 ft. Deep wells in Morehouse and Union Parishes encountered beds correlated with the Buckner formation and Smackover limestone of Arkansas, but the deeper tests farther west, in Bienville, Claiborne and Webster Parishes, did not find definite Buckner and Smackover sections; and there is still some doubt as to whether the deepest horizons reached were still Cotton Valley or the age-equivalents of the Smackover limestone. Excepting one well on a salt dome, none of the north Louisiana wells were drilled to the underlying rock salt, but one well in the Bethany gas field, Panola County, Texas, only 2½ miles west of the Louisiana line, reached the salt at 11,067 ft., and was drilled to 11,303 feet.

As a whole, the deep drilling tended to limit possibilities for very deep production. It was already known that porosity in the oölitic limestone beds of the lower Pine Island member and in the upper Travis Peak sands was of only local occurrence. Enough tests have now been drilled to show that the porosity in the Bodcaw sand zone of the upper Cotton Valley formation is not persistent; the Jones sand at the base of the Cotton Valley has been found only in the Schuler field in Arkansas; and satisfactory porosity and permeability in the Reynolds oölitic zone of the Smackover limestone has been found only in a limited area in Arkansas. Apparently the deposits of Smackover age become more sandy and shaly but less porous to the south of the area of typical limestone deposition.

A possibility that has been discussed by geologists in Louisiana and Texas is that the Travis Peak formation of Louisiana represents only the lower, nonmarine sand member of the type Travis Peak, while the upper fossiliferous Travis Peak beds of the outcrop section may be represented by the Pine Island member of the lower Glen Rose in this correlation.

TABLE 1.—*Oil and Gas Production in North Louisiana in 1938*

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[a]	To End of 1938	During 1938
1	Bear Creek, *Bienville*	2	0	1,000	0	0
2	Bellevue, *Bossier*	18	1,360	160	10,100,395	239,965
3	Bethany-Waskom, *Caddo*[1]	23	20	15,000	0	0
4	Caddo, *Caddo*[2]	35	32,500	5,000	153,957,190	2,361,655
5	Carterville, *Bossier*	15	720	2,720	1,534,810	40,950
6	Clayton, *Concordia*	8	0	60	0	0
7	Converse, *Sabine*	7	2,000	*x*	1,927,460	207,850
8	Cotton Valley, *Webster* (total)				19,360,065	3,386,415
9	Shallow, heavy oil	17	3,900	6,600	14,931,590	40,575
10	Holloway, light oil	3	1,400	0	1,900,760	1,634,115
11	Bodcaw, gas-distillate	2	12,000	*x*	2,277,743	1,461,753
12	Bodcaw, light oil	1			249,972	249,972
13	De Soto-Red River, *De Soto, Red River*	25	11,000	3,300	57,314,890	499,000
14	Driscoll, *Bienville*	3	0	1,000	0	0
15	Elm Grove, *Bossier, Caddo*	23	320	14,600	3,452,865	123,650
16	Epps, *East Carroll, West Carroll*	11	0	1,200	0	0
17	Haynesville, *Claiborne*	18	7,480	0	68,888,465	1,099,460
18	Holly, *De Soto*	9	80	160	933,570	31,310
19	Homer, *Claiborne*	20	3,020	0	68,270,175	950,535
20	Lake Bistineau, *Bienville*	23	0	2,000	0	0
21	Lisbon, *Claiborne, Lincoln*	2	7,320	0	5,722,650	3,330,470
22	Logansport, *De Soto*	1	0	2,000	0	0
23	Monroe, *Morehouse, Ouachita, Union*	23	0	270,000	0	0
24	Pleasant Hill, *Sabine*	12	800	0	1,521,040	38,605
25	Richland, *Richland*	13	0	49,280	0	0
26	Rodessa, *Caddo*	9	9,400[3]	7,800	51,854,900	13,631,720
27	Ruston, *Lincoln*	2	0	160	0	0
28	Sarepta, *Bossier, Webster*	17	570	1,120	1,526,385	56,310
29	Shongaloo, *Webster* (heavy)	18	70	5,680	108,580	2,650
30	Shongaloo, *Webster* (distillate)	½	160	0	39,825	39,825
31	Shreveport (Cross Lake), *Caddo*	½	1,000	*x*	113,570	113,570
32	Sibley (Dubberly), *Webster*	3	0	640	0	0
33	Simsboro, *Lincoln*	4	0	320	0	0
34	Sligo, *Bossier*	17	800	12,000	501,430	356,085
35	Sugar Creek, *Claiborne*	8	60	4,000	234,470	139,065
36	Sutherlin-Spider, *De Soto*	4	0	320	0	0
37	Urania, *Grant, La Salle, Winn*	14	3,700	0	23,291,815	1,016,585
38	White Sulphur Springs, *La Salle*	11	80	0	12,290	0
39	Zwolle, *Sabine*	11	7,200[4]	0	13,965,520	777,235
40	Total		96,960	406,120	484,632,360	28,442,910

[a] Footnotes to column heads and explanation of symbols are given on page 240.
[1] Includes the part of Bethany and Waskom fields in Louisiana; also Blanchard, Longwood, Greenwood, Cedar Grove, Spring Ridge and old Cross Lake areas.
[2] Includes Mooringsport, Trees City, Vivian, Hosston, Pine Island, Gilliam and Dixie areas.
[3] Most Rodessa acreage produces both oil and gas; classification of oil or gas wells depends on gas-oil ratios.
[4] Allowing 20 acres per producing well, but the Zwolle field is scattered over a much larger area.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					Oil-Production Methods at End of 1938			Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1938
				During 1938		At End of 1938		Number of Wells				Average at End of		Gravity A.P.I. at 60° F.
	To End of 1938[5]	During 1938[5]	Completed to End of 1938	Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Flowing	Pumping	Miscellaneous	Initial	1937	1938	Weighted Average
1	28	0	3	0	0	0	0	0	0	0	2,660	2,660	2,660	
2	2,371	113	413	23	0	141	1	0	141	[12]	y	y	y	19
3	18,232	787	180	1	8	0	46	0	0	0	1,880	y	y	{25
4	137,594	1,820	4,252	84	17	1,265	33	0	1,265	[12]	y	y	y	40}
5	17,031	51	155	0	14	37	0	0	37	0	1,250	y	y	42
6	11	0	1	0	0	0	0	0	0	0	630	630	630	
7	0	0	175	6	6	88	2	0	88	0	y	y	y	40
8	105,425	21,616	385	77	34	157	22							
9	x	x	279	0	34	51	22	0	51	0	y	y	y	25
10	x	x	31	30	0	31	0	31	0	0	y	y	y	50
11	x	x	69	41	0	69	0	69	0	0	e3,930	e3,930	e3,850	60
12	x	x	6	6	0	6	0	6	0	0	e3,930	e3,930	e3,850	42
13	63,973	1,319	1,428	14	0	166	27	0	166	[12]	y	y	y	40
14	3,483	1,708	4	1	0	0	5	0	0	0	{2,375 2,830}	2,055 2,600	{1,990 2,520}	
15	191,895	1,310	248	1	2	35	56	0	35	0	y	y	y	29
16	5,136	1,246	4	0	0	0	4	0	0	0	1,060	1,040	920	
17	2,714	801	766	0	5	291	0	0	291	[12]	y	y	y	36
18	123	15	15	1	2	5	2	0	5	0	y	y	y	38
19	5,953	361	629	2	2	355	0	0	355	[12]	y	y	y	35
20	2,125	78	13	1	0	0	0	0	0	0	2,310	2,310	2,310	
21	2,069	1,967	262	106	12	250	0	128	122	0	e2,000	e1,200	e 800	34
22	0	0	1	1	0	0	0	0	0	0	2,423		2,423	
23	2,431,985	172,443	1,264	53	0	0	1,176	0	0	0	1,020	50–1,000	50–1,000	
24	155	155	62	0	3	29	1	0	29	0	y	y	y	42
25	447,773	5,441	313	0	65	0	75	0	0	0	1,125	50 up	40–230	
26	219,775[6]	61,082	484	25	0	385[3]	86	255	63	67[13]	e2,780	e1,586	e1,019[14]	{44 65}
27	0	0	1	0	0	0	0	0	0	0	2,134	2,134	2,134	
28	25,581	12	44	1	0	6	0	0	6	0	1,200	0	0	25
29	71,240	225	91	0	9	1	4	0	1	0	1,200	y	y	29
30	463	463	1	1	0	1	0	1	0	0	y		y	64
31	100	100	8	8	0	7	1	7	0	0	e2,602		e2,500	44
32	57	57	4	0	0	0	0	0	0	0	y	y	y	
33	3,656	1,670	2	0	0	0	2	0	0	0	{2,100 2,620}	y 2,575	{1,119 2,540}	
34	73,194	15,898	116	13	34	21	60	10	0	11[13]	{1,890 2,200}	1,800 2,100	{1,700 2,000}	40
35	37,832	5,890	16	3	0	3	12	3	0	0	{1,800 2,310}	y	{350 2,100}	35
36	221	0	5	0	0	0	0	0	0	0	1,200	1,200	1,200	
37	6	0	503	17	19	256	0	0	256	0	y	0	0	18
38	0	0	12	0	0	0	0	0	0	0	y	0	0	20
39	179	15	360	28	19	62	0	0	62	0	y	0	0	40
40	3,870,380	296,643	12,220	467	251	3,561	1,615	510	2,973	78				

[5] Gas-production figures were supplied by Cyril K. Moresi, State Geologist, Louisiana Dept. of Conservation. Casing-head gas production is included, totaling 43,496 million cu. ft. in 1938, of which 34,600 million was from Rodessa. The grand total includes only 84,461 million cu. ft. of casinghead gas, as no records were kept in earlier years.

[6] The Rodessa Operators Committee estimates Rodessa gas production for 1938 as 64,026 million cu. ft. (39,123 million to pipe lines and 24,903 million to air); cumulative total to Dec. 31, 1938 as 406,386 million cu. ft. (193,357 million to pipe lines, 213,029 million to air).

[12] Gas injection into reservoir.

[13] Gas lift.

[14] Weighted average bottom-hole pressure; Dees-Young zone, 1314 lb.; Gloyd zone, 474 lb.; oil area average, 1019 lb.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1938	
	Name	Age[e]	Depth, Average in Feet[7]: Bottoms of Productive Wells	Depth, Average in Feet[7]: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
1	Pine Island Travis Peak	CreL	6,695 7,879	6,665 7,364	O, S	Por	*y*	A	Travis Peak	8,017
2	Nacatoch Rodessa	CreU CreL	370 1,035	360 1,010	S	Por	25	AF	Cotton Valley	6,137
3	[8]	CreU CreL	1,000– 5,900	[8]	S, O	Por	*y*	A	Cotton Valley	9,244
4	[9]	CreU CreL	1,000– 4,000	[9]	S, C, O, L	Por	*y*	Af	Cotton Valley	6,351
5	Buckrange Tokio	CreU	3,060 3,150	3,050 3,140	S	Por	9	A	Cotton Valley	10,066
6	Jackson	Eoc	1,438	1,415	S	Por	25	N	Wilcox	3,705
7	Saratoga-Annona, Paluxy, Rodessa	CreU CreL	1,922 3,232	1,617 3,150	C, L	Fis Por	*x*	Af	Travis Peak	8,929
8								A	Cotton Valley	9,187
9	Buckrange Rodessa	CreU CreL	2,547 4,650	2,532 4,500	S S, A, O	Por	11 *x*	A		
10	Travis Peak	CreL	5,987	5,692	S	10	15	AL		
11	Cotton Valley	L. Mes. ?	8,400	8,270	S	17	40	A		
12	Cotton Valley	L. Mes. ?	8,650	8,570	S	17	40	A		
13	[10]	CreU CreL	825–3,500	[10]	S, C	Por	*y*	AF	Pine Island	6,487
14	Rodessa Travis Peak	CreL	5,880 7,216	5,862 7,160	O, S	15	18 50	A	Travis Peak	7,693
15	Nacatoch, Ozan, Tokio	CreU	840 2,496	804 2,469	S	Por	*y*	A	Pine Island	5,382
16	"Monroe gas rock"	CreU	2,344	2,336	LS	Por	8	D	L. Cre, igneous	3,142
17	Buckrange	CreU	2,680	2,665	S	Por	25	A	Pine Island	5,092
18	Eagle Ford?	CreU	2,851	2,838	S	Por	11	NL	Paluxy?	3,373
19	Nacatoch Buckrange	CreU	1,345 2,065	1,280 2,040	S	Por	63	AF	Cotton Valley	4,504
20	Ozan, Tokio, Pine Island	CreU CreL	2,018 2,553 5,545	1,993 2,544 5,144	S O	Por	50	Af	Travis Peak	5,777
21	Pine Island	CreL	5,300	5,275	O	20	10	N	Travis Peak	5,851
22	Rodessa	CreL	5,187	4,953	O	Por	30	A	Rodessa	5,187
23	"Monroe gas rock"	CreU	2,205	2,145	LS	23	50	A	Cotton Valley	7,021
24	Paluxy	CreL	3,237	3,175	L, S	Por	16	Nf	Glen Rose	5,063
25	"Monroe gas rock," Tokio, Rodessa	CreU CreL	2,447	2,349	S, L S	Por	76	A	Cotton Valley	9,986
26	Rodessa	CreL	5,600 6,100	5,560 6,075	S, L, L S, O	5–35	5–80	AF	Pre-Cre. salt	11,486
27	Pine Island	CreL	5,822	5,316	O	Por	10	A	Travis Peak	5,822
28	Buckrange	CreU	2,700	2,681	S	Por	11	A	Rodessa	5,120
29	Buckrange	CreU	2,680	2,665	S	20	12	A		
30	Cotton Valley	L. Mes?	10,462	8,990	S	Por	20	A	Cotton Valley?	10,462
31	Pine Island	CreL	5,581	5,550	O	Por	15	A	Travis Peak	6,025
32	Rodessa	CreL	6,112	5,570	O	Por	40	A	Travis Peak	7,202
33	Rodessa Travis Peak	CreL	5,301 6,576	5,282 6,451	O, S	Por	30	A	Travis Peak	7,023
34	[11]	CreU CreL	850–5,200	[11]	S, O	Por	30	A	Travis Peak	6,112
35	Rodessa Pine Island-Travis Peak	CreL	4,400 5,730	4,370 5,700	O S, SL	18 Por	13 50	A	Cotton Valley?	10,759
36	Paluxy	CreL	2,850	2,840	S	Por	10	AL	Pine Island	5,930
37	Cane River-Wilcox	Eoc	1,530	1,520	S	Por	9	MU	Tokio	6,463
38	Jackson	Eoc	804	794	S	Por	9	NF	Wilcox	2,435
39	Saratoga-Annona, Paluxy	CreU CreL	2,500	2,100	C L	Fis	*x*	Af	L. Glen Rose	7,155
40										

[7] There is no longer any definite relation between top of productive zone, bottoms of productive wells and thickness of producing formation, since many wells are completed through casing perforations.

[8] Different areas produce from Nacatoch at about 1000 ft.; Buckrange, 1950; Tokio-Paluxy, 2300; Rodessa, 4650; Pine Island, 5850; Travis Peak, 5900 to 6000.

[9] Production from Nacatoch at about 1000 ft.; Saratoga-Annona chalk, 1500 to 1600; "Blossom," 1825; Tokio-Paluxy, 2250 to 2400; and at Pine Island, from Rodessa Glen Rose, 2800 to 3000; Pine Island Glen Rose, 3700 to 3800; Travis Peak, 4000.

[10] Production from Nacatoch at about 800 ft.; Saratoga-Annona chalk, 1400; Eagle Ford-Paluxy, 2600; gas from Paluxy?, 3500.

[11] Production from Nacatoch at about 850 ft.; Buckrange, 1725; Tokio, 2450; Paluxy, 2750 and 3100; Rodessa, 4100 to 4275; Pine Island (Pettit zone), 5100 to 5200.

Determination of this point must await more drilling in eastern Texas and careful study of the fossils.

New Field

Shreveport.—On July 15, 1938, R. E. Allison's No. 1 Ellerbe et al., sec. 27, T. 18 N., R. 14 W., Caddo Parish, was completed through casing perforations at 5548 to 5570 ft., in the Pettit zone of the Pine Island member, producing 500 bbl. per day of 43.8° gravity oil through ¼-in. choke, with gas-oil ratio of 591 to 1 and bottom-hole pressure of 2602 lb., as the discovery well in the Shreveport oil field. The well had been drilled to a depth of 6025 ft., and tested salt water in the upper Travis Peak sand at 5824 to 5858 feet.

This well is less than a mile northwest of the Shreveport City Limits, and production was soon found in the northern part of the city. The oil field partly underlies the old shallow Cross Lake gas field, which formerly produced principally from the Nacatoch sand. By the end of 1938, eight producing wells had been completed, and a salt-water well ½ mile

Table 2.—*Summary of Drilling Operations in Louisiana in* 1938

Important Wildcats Drilled in 1938

	Parish	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
		Sec.	Twp.	Rge.			
1	Bienville	25	14 N	8 W	10,770	Wilcox	Cotton Valley
2	Bienville	18	16 N	9 W	5,777	Wilcox	Travis Peak
3	Caddo	27	18 N	14 W	6,025	Wilcox	Travis Peak
4	Caddo	34	22 N	16 W	4,865	Claiborne	Rodessa
5	Claiborne	5	19 N	5 W	10,759	Claiborne	Cotton Valley?
6	Concordia	35	5 N	8 E	6,105	Pleistocene	Wilcox
7	De Soto	26	12 N	16 W	5,187	Wilcox	Rodessa
8	Madison	3	15 N	11 E	4,334	Pleistocene	Rock salt
9	Morehouse	10	20 N	7 E	7,032	Pleistocene	Igneous rock
10	Red River	12	12 N	11 W	6,487	Wilcox	Pine Island
11	Red River	20	11 N	9 W	7,155	Wilox	Travis Peak
12	Sabine	23	7 N	14 W	4,208	Wilcox	Paluxy
13	Sabine	8	9 N	13 W	8,929	Wilcox	Travis Peak
14	Union	14	21 N	1 E	9,983	Claiborne	Smackover
15	Webster	36	21 N	10 W	8,642	Claiborne	Cotton Valley
16	Webster	3	20 N	10 W	8,686	Claiborne	Cotton Valley
17	Webster	21	21 N	10 W	8,725	Claiborne	Cotton Valley
18	Webster	5	20 N	10 W	9,187	Claiborne	Cotton Valley
19	Webster	32	23 N	9 W	10,462	Claiborne	Cotton Valley?
20	Webster	17	23 N	11 W	10,070	Claiborne	Cotton Valley

northwest of the discovery established the limit of the field in that direction. Only one of the completed wells was rated as a gas well, but some of the others have high gas-oil ratios. The structure is not yet defined, but evidently is a very flat anticline with small closure. The gas well is only 24 ft. higher structurally, on the top of the producing bed, than the salt-water well. The producing formation consists of two or three beds of porous, oölitic limestone separated by tight or shaly layers, in a 70-ft. interval, but in general only one 10 to 15-ft. bed carries oil at any one location.

Three tests drilled on the south edge of Shreveport, 3 to 8 miles from the producing area, not only ran 70 to 80 ft. lower on structure, but the

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U.S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Gulf Refining Co.						Dry
2	De Soto Oil & Gas Co.	Distillate	40	Open	2,275	2,275	Extends Lake Bistineau field 3 miles east Perforated 5,080–5,090
3	R. E. Allison	500	0.3	¼	1,525	1,325	Discovery well, Shreveport oil field. Perforated 5,548–5,570
4	Colonial Corporation	464	*x*	2-in. tbg.	650	135	Extends Vivian pool, old Caddo field, 1½ miles northwest. Perforated 2,449–2,475, in Tokio-Paluxy sand.
5	Union Producing Co.						Deepened from 5,730. Dry at total depth, may be plugged back and recompleted as a gas well at original depth
6	Benedum & McCormick						Dry
7	The Hunter Co., Inc.	Distillate	4.25	Open	2,423	2,423	Extends Logansport field 4 miles northeast. Perforated 4,953–5,029
8	Continental Oil Co.						Dry. Discovery of a new salt dome
9	W. J. Furlong et al.						Dry
10	Magnolia Petroleum Co.						Dry. Deepest test in Bull Bayou field
11	Ark. Fuel Oil Co.						Dry. Lake End area
12	Sutton-Zwolle Oil Co.	984	5	⅜	900	*x*	Discovery of deeper producing zone in Blue Lake area, Zwolle field
13	Republic Nat. Gas Co.						Deepened from 8,517, did not reach Cotton Valley formation
14	Joe Modisette et al.						Dry. Farmerville area
15	Stanolind Oil & Gas Co.	944	0.6	¼	1,175	1,125	Discovery oil well, Bodcaw sand, southeast flank of Cotton Valley
16	Midstates Oil Corporation	360	0.3	⅛	1,480	1,400	Discovery oil well, "D" sand, south flank of Cotton Valley. Perforated 8,502–8,533
17	N. Am. Oils, Consol.	648	0.8	½	1,000	275	Bodcaw sand oil well, northeast flank of Cotton Valley. Plugged back to 8,685
18	Oliphant Oil Corporation						Dry. Deepest test and first Bodcaw dry hole, defining Cotton Valley field on southwest
19	Magnolia Petroleum Co.	279 dist.	3	11/32	1,700	1,625	Deep discovery well, Shongaloo field. Perforated 8,990–9,010
20	Magnolia Petroleum Co.						Dry. Northeast of Carterville field

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1938	56	12
Number of oil wells completed during 1938	349	1
Number of gas wells completed during 1938	116	1
Number of dry holes completed during 1938	93	47

Pettit zone had practically no porosity; indicating that oil accumulation in the field may be localized by variations in porosity, as well as by structure.

Extensions and Developments

Cotton Valley.—Cotton Valley was one of the active fields in 1938. There were 30 oil wells completed in the Holloway sand, which seems to be limited to two lenses on the northeast and southwest flanks of the structure; and also 41 gas and distillate wells in the Bodcaw sand.

An important development was the discovery of oil in sands of the Cotton Valley formation on the flanks of the structure. The Stanolind Oil & Gas Company's No. D-1 Pardee Co., sec. 36, T. 21 N., R. 10 W., on the southeast flank of the field, was completed June 6, flowing 944 bbl. per day of 39.6° gravity oil from the lower part of the Bodcaw sand at 8607 to 8642 ft. On July 9 the Midstates Oil Corporation's No. 1 Welori Lumber Co., sec. 3, T. 20 N., R. 10 W., was completed for 360 bbl. per day of 44.4° gravity oil at 8502 to 8532 ft. (total depth 8626 ft.) in the "D" sand, which occurs 90 to 100 ft. above the Bodcaw sand. At the end of the year three wells were producing oil from the Bodcaw and three from the "D" sand, one of the latter being the Standard Oil Co. and Oliphant's No. 1 Stewart, which was a Bodcaw sand gas-distillate producer, plugged back and reperforated in the "D" sand. However, a test ⅜ mile southwest of this well showed salt water in both Bodcaw and "D" sands, indicating that deep oil production will be confined to a narrow belt around the structure.

Lisbon.—During 1938 the proved area of the Lisbon field was almost doubled, with 106 oil wells completed, 88 in Claiborne and 18 in Lincoln Parish. This practically completes drilling in the field, as it was outlined by eight dry holes around the south and east edges and by very small wells on the north. Spacing was changed from 20 to 40 acres per well, as it became evident that wells drilled on 20 acres would hardly pay out. Twelve producing wells were abandoned, mostly along the north edge of the field, where the producing formation has little porosity, although it is structurally the highest part of the field; and almost half of the wells were on the pump.

Logansport.—The Hunter Company's No. 1 Parker, sec. 26, T. 12 N., R. 16 W., De Soto Parish, 2 miles northeast of Logansport, was completed June 2, 1938 with estimated open-flow potential of 4,250,000 cu. ft. per day of gas and closed pressure of 2423 lb. Total depth is 5187 ft., but completion was through casing perforations at 4953 to 5029 ft., in the Rodessa member of the Glen Rose, about 100 ft. below the base of the massive anhydrite.

This is considered an extension well, because there were already three gas wells on the same structure in Shelby County, Texas, about 4 miles

southwest of the No. 1 Parker. Although not a large well, this helps to prove a considerable area and gas reserve in the Rodessa zone on the Logansport structure.

Rodessa.—Rodessa remained the most important producing area, yielding about 48 per cent of the total north Louisiana oil production, although drilling is practically completed. Only two producing wells were completed during the last eight months of 1938. Bottom-hole pressure has declined rapidly, especially in the Gloyd zone, where it averages less than 500 lb. According to the Rodessa Operators Committee, 118 wells were making more than 1 bbl. per day of salt water, and 87 making smaller amounts; and the total water production in December 1938 was estimated at 12,992 bbl. per day.

Shongaloo.—The first deep test on the Shongaloo structure, where gas and a little oil have been produced from the Buckrange sand since 1921, was the Magnolia Petroleum Company's No. 1 Sexton Unit, sec. 32, T. 23 N., R. 9 W. This well reached the top of the Cotton Valley formation at 7600 ft. and was drilled 2862 ft. deeper, to a total depth of 10,462 ft. As in other deep tests at Sugar Creek and Rodessa, this well did not find any typical Buckner anhydrite and Smackover limestone, but it is possible that the last 600 ft. represented beds equivalent to the Smackover limestone in age.

The well was completed June 3, through casing perforations at 8990 to 9010 ft., producing 279 bbl. per day of 64° gravity distillate with 2,900,000 cu. ft. of gas through $^{11}/_{32}$-in. choke. The producing sand is lower in the Cotton Valley formation than the Bodcaw and associated sands at Cotton Valley. Two other deep wells in this field were drilling at the end of the year.

Deep Gas Fields.—The year 1938 was another one of little development in the deep gas fields. At Lake Bistineau, Bienville Parish, one well was drilled, extending the producing area of the Pine Island member about 3 miles east.

At Sligo, Bossier Parish, only two Pine Island (Pettit zone) gas wells were completed, but there were also 11 oil wells in the 3100-ft. zone, discovered late in 1937.

At Sugar Creek, Claiborne Parish, two gas wells and one oil and gas well were completed in the Pine Island–Travis Peak contact zone. One old well, the Union Producing Company's No. 2 Brownfield, was deepened to 10,759 ft. and temporarily abandoned as dry at that depth, but will probably be recompleted by perforating casing in the former producing zone. This well penetrated 2970 ft. below the top of the Cotton Valley formation without finding any typical Buckner formation and Smackover limestone, although there is some doubt as to whether the lowest beds were still Cotton Valley formation, or were the age-equivalent of the Smackover limestone.

Other completions were one Rodessa zone well at Driscoll, Bienville Parish and one in the Travis Peak at Longwood, Caddo Parish.

Old Fields.—Activity continued in the old Caddo shallow fields, with 83 oil wells, 1 gas well, and 27 dry holes completed. In December, the Colonial Corporation's No. 1 Thigpen-Herold, sec. 34, T. 22 N., R. 16 W., after drilling through the Rodessa member to a total depth of 4265 ft., was plugged back and completed in the Tokio-Paluxy sand at 2475 ft., flowing 464 bbl. per day of light oil. This well opened an extension to the old field southwest of Vivian, and caused a number of other wells to be started at the beginning of 1939.

Drilling in and around the De Soto-Red River field was unimportant, resulting in only 7 small oil wells, 7 gas wells, and 17 dry holes. The Magnolia Petroleum Company's No. 59 Pugh, sec. 12, T. 12 N., R. 11 W., Red River Parish, the deepest test ever drilled in the field, was dry at 6488 ft. It had some porous beds carrying salt water at 5160 to 5230 ft., in the Rodessa member from 160 to 230 ft. below the massive anhydrite, but there was practically no porosity below this. The Travis Peak was not quite reached. In the Lake End area of Red River Parish, southeast of the De Soto-Red River field proper, the Arkansas Fuel Oil Company's No. 1 Franklin Realty Co., sec. 20, T. 11 N., R. 9 W., was also dry in the upper Travis Peak at 7155 ft. No other deep tests were drilled in these two parishes, except the gas well at Logansport, previously mentioned.

At Zwolle, the discovery of an extension of the chalk producing area just south of the town of Zwolle led to a renewal of drilling activity, so that 28 oil wells and 26 dry holes were drilled in 1938, while oil production almost tripled. In May, the Sutton-Zwolle Oil Company's No. 1 Sabine Lumber Co., sec. 23, T. 7 N., R. 14 W., in the Blue Lake area, blew in while coring at 4208 ft., making 41 bbl. per hour of oil; production probably coming from a break at 3845 to 3855 ft., in the upper part of the Lower Cretaceous, probably the Paluxy formation. Although this well continued to be a good producer, it was evidently a freak, because four other tests in the vicinity were drilled to greater depths without finding even a showing of oil.

The old Bellevue and Urania shallow fields continued among active areas, with respectively 23 and 17 oil wells completed.

The Monroe gas field had 53 new gas wells, of which 18 were in Morehouse Parish, 3 in Ouachita, and 32 in Union; a decrease from the 87 completed in 1937. In 1938 the Monroe field produced 58.1 per cent of the north Louisiana total, and this field has made 62.8 per cent of the total cumulative production recorded up to the end of 1938.

Other Deep Tests.—Deep wildcat tests not previously mentioned include the following:

In Bienville Parish, sec. 25, T. 14 N., R. 8 W., the Gulf Refining Company's No. 1 Good Pine Oil Co. was drilled to 10,770 ft., and is still the

second deepest in north Louisiana. It was drilled on geophysical data, being 6 miles south-southeast of the Castor salt dome and 8 miles west-southwest of the Prothro dome. It went over 1100 ft. into the Cotton Valley formation, topped at about 9650 ft. There was salt water in the Rodessa zone just below the anhydrite, but no satisfactory porosity was found in lower formations.

In Madison Parish, sec. 3, T. 15 N., R. 11 E., the Continental Oil Company's No. 1 Singer Mfg. Co. found anhydrite cap rock at 4011 ft. and rock salt at 4196 ft., total depth 4334 ft.; proving a new interior salt dome. This location is near the center of the Mississippi Basin, and is 70 miles east of Sikes, the nearest previously known dome in Louisiana, but is only 45 miles from the Edwards salt dome in Mississippi. Several more salt domes are reported as located by geophysical methods in the Mississippi River bottoms.

In Morehouse Parish, sec. 10, T. 20 N., R. 7 E., W. J. Furlong et al.'s No. 1 Clark, total depth 7032, was the first deep test east of the Monroe gas field. The Cotton Valley formation was found at about 2900 ft., and at 6140 a formation of sandy limestone and limy shale, believed to be equivalent to the Smackover limestone in age, was encountered. The bottom of the hole was in igneous rock, probably a dike or sill.

In Union Parish, sec. 14, T. 21 N., R. 1 E., the Standard Oil Company of Louisiana and Joe Modisette's No. 1 Frost Lumber Industries was drilled to 9983 ft. This is on the large, flat "Farmerville high" where a number of shallow tests had been drilled previously. The Cotton Valley formation was found at 6160 ft. and the Smackover limestone equivalent at 9548 ft., but no satisfactory porosity and saturation were found, and the test was abandoned as dry.

In Webster Parish, sec. 17, T. 23 N., R. 11 W., the Magnolia Petroleum Company's No. C-1 Pardee Lumber Co. drilled to 10,070 ft., or 2135 ft. below the top of the Cotton Valley Formation. The location is 3 miles northeast of the Carterville shallow producing area. This well found little porosity in the Travis Peak and Cotton Valley formations. There was a showing of oil in the Pine Island member between 5925 and 5990 ft. but testing did not develop any production.

Prospects for 1939

A considerable decrease in drilling activity is to be expected in 1939, as Rodessa and Lisbon are almost completely drilled up, and the only discovered fields calling for much additional drilling are Cotton Valley and Shreveport. At the beginning of 1939, deeper tests were drilling at Lake Bistineau and Sibley, but no extensive drilling in the deep gas fields is probable until the Monroe production starts to decline or demand for gas increases. A few other very deep tests are projected on known structures or geophysical prospects.

Oil production should remain approximately the same as in 1938. Proration allowables have been liberal during the past year, but increases in production in the Cotton Valley and Shreveport fields should make up for the natural decline at Rodessa, Lisbon and older fields.

Acknowledgments

Oil-production statistics were supplied chiefly by the Scouting Department of the Standard Oil Company of Louisiana, B. Peters, Chief Scout. Other information has been obtained from almost all geologists in the area, in particular from Clarence L. Moody, Chester C. Clark, Roy T. Hazzard, and Louis A. Barton.

Oil and Gas in Michigan during 1938

By Theron Wasson,* Member A.I.M.E.

(New York Meeting, February, 1939)

Michigan reports another record year. Its production of 18,605,000 bbl. exceeds any previous year's total and is 2,000,000 bbl. over 1937, the previous record year. Production in 1938 brings the accumulated total for the state to a little over 100,000,000 bbl. It has taken 14 years to reach this accumulative figure, which would meet the needs of our country for about one month.

Twelve new oil and gas fields were opened in 1938 and 978 tests for oil and gas were completed, of which 566 were oil wells, 25 gas wells and 387 dry holes. The new oil discovered is probably about equal to the oil produced during the year.

Activities in 1938

The Temple field, Clare County, was the discovery of the year. Since July, 46 wells have been completed, and although not yet outlined it appears that more than 2000 acres have been proved for production from the Monroe of Devonian age, at a depth of 3900 ft. This discovery is the result of a wildcat test along a trend northwestward from the older fields of the central basin. The Edenville pool, Midland County, ranks second among the new fields. Thirty-five producing wells have been drilled to the Dundee at 3800 feet.

The surprise development was in southwestern Michigan, Allegan and Van Buren Counties, where six new Traverse lime pools were opened with a daily production of about 8000 bbl. at the end of the year. This is the first consistent Traverse production in the state and is about 100 miles southwest of the producing areas of the central basin. These fields have had a rapid development because of the shallow depths, which range from 900 to 1500 ft. Bloomingdale, Van Buren County, had a town-lot boom, and 72 wells have been drilled there since August 1938. Small operators from many states have been attracted to this shallow territory, and the coming year will see much drilling in these and surrounding counties.

The Buckeye field, Gladwin County, led the state in amount of oil produced. Its total of over 7,000,000 bbl. was far ahead of that of any other pool.

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The old fields of the Midland-Isabella area maintained a steady production from many wells, which are now from 7 to 10 years old.

Some minor gas discoveries were made but the Six Lakes gas field, now 4 years old and with 212 producing wells, stands as Michigan's largest gas reserve.

Exploration

Exploration has continued during the year with an increasing interest in the counties lying to the north and northwest of the central basin. This is an area where glacial drift from 200 to 700 ft. thick must be pene-

Fig. 1.—Oil and gas fields of Michigan in 1938.

trated before structural markers are found. Shallow drilling has been carried on by some companies to depths of 1200 ft. or more where the Marshall sandstone is used as a datum.

Some reflection seismograph work has been done in the central basin and experiments made in southwestern Michigan may lead to its further use there. The glacial cover is a source of trouble in using this method.

The important wildcats drilled during the year were in the south half of the lower peninsula. The deepest test was drilled in Midland County to a depth of 5195 ft., where it was abandoned in the Lower Monroe. An attempt to classify the 300 wildcat tests drilled during

the year shows that 199 were blind wells, drilled without geological guidance; 50 of these were blind tests near production. Out of the 199 tests, 9 produced oil or gas; that is, 4.5 per cent were successful.

Wildcats drilled on structures outlined by geological work were 18 per cent successful, as out of 101 tests of this class 18 discovered oil or gas.

All new fields are producing from previously known horizons. A few wells have found small production in the Monroe at greater depths than

TABLE 1.—*Oil and Gas Production in Michigan in* 1938

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells				
										During 1938		At End of 1938	
			Oil	Gas[a]	To End of 1938	During 1938	To End of 1938	During 1938	Completed to End of 1938	Completed	Abandoned	Producing Oil[b]	Producing Gas[c]
1	Saginaw, *Saginaw*	14	1,800	0	1,301,675	28,342	0	0	282	0	0	55	0
2	Gratiot, *Gratiot*	12	0	400	0	0	4	0	3	0	0	0	0
3	Mt. Pleasant, *Isabella-Midland*	11	8,000	0	20,253,987	583,381	2,771	437	440	0	50	220*y*	0
4	Muskegon, *Muskegon*	11	2,700	0	6,568,226	59,510	6,685	121	411	0	21	74	17
5	Broomfield, *Isabella*	9	0	4,100	0	0	5,432	446	54	0	6	0	41
6	Clare (McKay), *Clare*	9	0	400	0	0	586	84	9	0	1	0	8
7	Leaton, *Isabella*	9	2,100	480	2,447,417	213,113	164	29	90	0	15	50	3
8	Vernon, *Isabella*	9	1,100	880	3,789,907	256,069	1,225	87	91	0	5	41	8
9	Porter-Yost Clark, *Midland*	7	8,100	0	32,977,275	2,629,837	3,454	592	517	4	39	387	0
10	Hart, *Oceana*	6	160	0	116,275	0	0	0	17	0	0	0	0
11	Big Rapids, *Mecosta*	5½	0	2,200	0	0	5,210	1,050	27	0	4	0	15
12	Edmore, *Montcalm*	5	160	0	363,255	31,145	36	0	13	0	5	7	0
13	Ogemaw, *Ogemaw*	5	5,000	0	3,054,676	753,081	0	0	242	29	4	238	0
14	Beaverton (N. & S.), *Gladwin*	4	580	0	555,120	88,629	0	0	28	0	5	23	0
15	Birch Run, *Saginaw*	4	300	0	156,200	20,078	0	0	28	0	3	25	0
16	Six Lakes, *Mecosta-Montcalm*	4	0	10,120	0	0	11,704	4,693	242	0	14	0	212
17	Crystal, *Montcalm*	3½	2,180	200	6,870,856	239,879	331	40	240	1	43	45	6
18	New Haven, *Gratiot*	3	0	2,400	0	0	1,253	561	48	1	2	0	45
19	Buckeye (N & S), *Gladwin*	2½	5,170	0	13,824,366	7,385,592	0	0	467	135	50	411	0
20	Ravenna, *Muskegon*	2½	0	4,320	0	0	773	296	27	0	0	0	27
21	Clayton, *Arenac*	2¼	1,300	560	2,196,442	1,108,310	8	8	61	15	4	50	7
22	Sherman, *Isabella*	2¼	1,110	0	2,717,424	1,152,310	418	418	83	21	10	62	2
23	Adams, *Arenac*	1½	400	0	66,758	53,344	0	0	13	8	1	12	0
24	Bentley, *Gladwin*	1½	1,000	0	224,533	217,193	0	0	35	32	0	35	0
25	Salem, *Allegan*	1½	1,100	0	1,336,311	920,647	0	0	102	50	7	95	0
26	Dorr, *Allegan*	1	360	0	125,030	125,030	0	0	23	23	3	20	0
27	Edenville, *Midland*	1	400	0	603,916	603,916	0	0	35	35	4	31	0
28	Clare City, *Clare*	¾	0	400	0	0	106	106	5	5	0	0	5
29	Monterey, *Allegan*	¾	300	0	228,811	228,811	0	0	25	25	1	24	0
30	Bloomingdale, *Van Buren*	½	510	0	320,393	320,393	0	0	72	72	0	72	0
31	Diamond Springs, *Allegan*	½	570	0	469,212	469,212	0	0	53	53	0	53	0
32	Overisel, *Allegan*	½	300	0	145,472	145,472	0	0	20	20	0	20	0
33	Temple, *Clare*	½	2,000	0	873,030	873,030	0	0	39	39	0	38	1
34	Home Twp, *Montcalm*	¼	0	1,200	0	0	52	52	6	6	0	0	6
35	Mill Lake, *Van Buren*	¼	*x*	*x*	3,679	3,679	0	0	4	4	0	4	0
36	Winfield, *Montcalm*	¼	0	1,500	0	0	81	81	7	7	0	0	7
37	Wise, *Isabella*	¼	*x*	*x*	8,289	8,289	0	0	2	2	0	2	0
38	Miscellaneous	0	0	0	303,435	86,855	32	32	39	19	0	31	8
39	Total		46,700	29,160	101,901,970	18,605,152	40,325	9,133	3,900	606	297	2,125	418

[a] Footnotes for column headings and explanation of symbols are given on page 240.

previously known. It will take more testing to demonstrate the value of these deeper horizons.

Drilling Methods

Cable tools are still used in most fields, particularly in the new areas of southwestern Michigan. The rotary method has been used to some extent for drilling through the drift in the central basin. This year the

Table 1.—(*Continued*)

	Oil-production Methods at End of 1938		Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1938	Producing Formation								Deepest Zone of 1938	
	Number of Wells			Average at End of		Gravity A.P.I. at 60° F.			Depth, Average in Feet							
Line Number	Flowing	Pumping	Initial	1937	1938	Weighted Average	Name	Age[e]	Bottoms of Productive Wells	To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness Average in Feet	Structure[h]	Name	Depth of Hole Ft.
1	0	55	*x*	*x*	*x*	44.3	Berea	Mis	1,850	1,820	S	P	16	A	Sylvania	3,970
2	0	0	*x*	*x*	*x*	0	Parma	Pen	510	500	S	P	10	MCY	Dundee	3,100
3	0	222	*x*	*x*	*x*	41.5	Dundee	Dev	3,573	3,542	L	P	15	A	Sylvania	4,821
4	0	78	*x*	*x*	*x*	37.4	Trav Dun	Dev	2,075	2,050	L	P	10	A	St. Peters	4,754
5	0	0	550	*x*	180	0	Stray-Mar	Mis	1,350	1,300	S	P	5	A	Monroe	3,788
6	0	0	605	*x*	135	0	Stray-Mar	Mis	1,413	1,408	S	P	5	A	Monroe	4,055
7	0	51	550	*x*	150	43	Stray-Mar Dundee	Mis Dev	G-1,243 O-3,681	G-1,239 O-3,644	S L	P	O-4 O-7½	A	Monroe	4,390
8	0	41	575	*x*	210	44.1	Monroe	Dev	3,744	3,741	Dol	P	3	A	Monroe	3,907
9	0	392	*x*	*x*	*x*	41.3	Dundee	Dev	3,434	3,422	L	P	12	A	Monroe	3,677
10	0	0	*x*	*x*	*x*	34.	Traverse	Dev	1,890	1,880	L	P	4	A	Dundee	2,407
11	0	0	502	*x*	330	0	Stray-Mar	Mis	1,410	1,390	S	P	10	A	Monroe	4,042
12	0	8	900	*x*	*x*	43.2	Trav	Dev	3,112	3,108		P	4	A	Dundee	3,700
13	0	238	*x*	*x*	*x*	33.4	Trav Dundee	Dev	T-1,810 D-2,707	T-1,800 D-2,622	L L	P	T-5 D-20	A	Monroe	3,637
14	0	23	*x*	*x*	*x*	41.3	Dundee	Dev	3,895	3,880	L	P	12	A	Dundee	4,025
15	0	25	*x*	*x*	*x*	42.4	Berea	Mis	1,546	1,529	S-D	P	13	A	Dundee	2,760
16	0	0	515	*x*	402	0	Stray-Mar	Mis	1,275	1,300	S	P	16	A	Monroe	3,529
17	0	47	G-448	*y*	G-404	41.3	Stray-Mar Monroe	Mis Dev	G-1,021 O-3,191	G-1,016 O-3,201	S D	P	4	A	Monroe	3,520
18	0	0	448	*x*	404	*y*	Stray-Mar	Mis	950	975	S	P	5	A	Dundee	3,657
19	0	413	*x*	*x*	*x*	36	Dundee	Dev	3,627	3,599	L	P	9½	A	Monroe	4,330
20	0	0	720	*x*	475	0	Berea	Mis	1,233	1,212	S-D	P	10	*y*	Dundee	2,306
21	0	52	*x*	*x*	*x*	34.3	G-Berea O-Dundee	Mis Dev	G-1,214 O-2,576	G-1,205 O-2,534	S L	P	12	A	Dundee	2,707
22	0	62	*x*	*x*	*x*	47.8	Monroe	Dev	3,652	3,648	D	P	4	A	Monroe	4,031
23	0	12	*x*	*x*	*x*	T-37 D-34.3	Traverse Dundee	Dev	T-2,039 D-2,964	T-2,020 D-2,809	L	P	T-15 D-16	A	Dundee	2,964
24	0	35	*x*	*x*	*x*	41.4	Dundee	Dev	3,540	3,502	L	P	26	A	Dundee	3,685
25	0	97	*x*	*x*	*x*	41.5	Traverse	Dev	1,601	1,587	L	P	8	A	Dundee	1,950
26	0	21	*x*	*x*	*x*	41.1	Traverse	Dev	1,607	1,596	L	P	4	A	Monroe	1,932
27	0	34	*x*	*x*	*x*	41.3	Dundee	Dev	3,796	3,788	L	P	8	A	Dundee	4,015
28	0	0	605	*x*	559	0	Stray-Mar	Mis	1,295	1,285	S	P	5½	A	Monroe	3,865
29	0	25	*x*	*x*	*x*	*y*	Traverse	Dev	1,648	1,638	L	P	3	A	Traverse	1,808
30	0	72	*x*	*x*	*x*	41.2	Traverse	Dev	1,219	1,216	L	P	2½	A	Monroe	1,693
31	0	53	*x*	*x*	*x*	*y*	Traverse	Dev	1,473	1,466	L	P	4	A	Traverse	1,571
32	0	20	*x*	*x*	*x*	41.7	Traverse	Dev	1,481	1,471	L	P	3	A	Traverse	1,490
33	38	0	*x*	*x*	*x*	43.8	Monroe	Dev	3,898	3,890	D	P	4	A	Monroe	3,923
34	0	0	*x*	*x*	*x*	0	Stray-Mar	Mis	1,306	1,284	S	P	4	A	Monroe	3,505
35	*y*	*y*	515	*x*	502	*y*	Traverse	Dev	1,279	1,277	L	P	2	A	Traverse	1,495
36	0	0	446	*x*	439	0	Stray-Mar	Mis	1,138	1,128	S	P	8	A	Dundee	3,430
37	2	0	*x*	*x*	*x*	43.	Dundee	Dev	3,716	3,702	L	P	10½	A	Dundee	3,723
38	0	31	*x*	*x*	*x*	*y*			*x*	*x*						
39																

TABLE 2.—*Summary of Drilling Operations in Michigan*

Important Wildcats Drilled in 1938

	County	Location			Total Depth, Ft.	Deepest Horizon Tested[1]	Drilled by	Initial Production per Day	Remarks
		Survey	Lat.	Long.				Oil, U. S. Bbl.	
1	Ottawa.....	36	5 N	14 W	1,712	Traverse	Morris-Sutherland Drill, Co.	6	Important Traverse showing stimulated prospecting in area
2	Bay........	1	14 N	4 E	2,956	Dundee	Gulf Rfg. Co.	60	Demonstrated production on structure caused additional prospecting
3	Midland	27	16 N	1 W	3,796	Dundee	Chapman Oil Co. & Asso. Petr.	1,000	Discovery well, Edenville field
4	Allegan.....	9	3 N	13 W	1,620	Traverse	Sim B. Hood, Tr.	750	Disc. well, Monterey field
5	Allegan.....	29	4 N	12 W	1,623	Traverse	Eureka Dev. Co.	250	Disc. well, Dorr field
6	Montcalm..	29	11 N	8 W	2,837	Traverse	Gentry Engineering Co.	85	Has produced 8,713 bbl. oil since discovery. Will lead to additional prospecting
7	Allegan.....	3	1 N	12 W	1,552	Traverse	Crystal Synd., Inc.	45	Important showing
8	Isabella.....	5	13 N	5 W	3,700	Monroe	Bell & Marks, Inc.	74	Non-commercial but stimulated prospecting
9	Clare.......	35	17 N	4 W	1,320	Stray-Marshall	James A. McKay	7	Discovered oil in stray sandstone
10	Tuscola.....	30	14 N	8 E	3,427	Monroe	Norton & Kramer	70	Production from a "pay zone" 425 ft. below top of Monroe
11	Avenac.....	26	19 N	3 E	2,978	Dundee	Pure Oil Co.	83	Discovered Dundee oil, Adams field
12	Clare.......	3	18 N	6 W	3,894	Monroe	S. J. Higelmire, Tr.	878	Discovery well, Van Horn field
13	Allegan.....	24	4 N	13 W	1,687	Traverse	A. G. Allen	5	Significant showing
14	Allegan.....	36	4 N	14 W	1,461	Traverse	Wm. J. Cline	836	Discovery well, Diamond Springs field
15	Isabella.....	28	16 N	3 W	3,723	Dundee	Turner Petr. Co.	85	Discovery well, Wise field
16	Allegan.....	21	4 N	14 W	1,473	Traverse	Stewart Oil Co.	200	Discovery well, Overisel field
17	Van Buren..	9	1 S	14 W	1,222	Traverse	Fisher & McCall	1,337	Discovery well, Bloomingdale field
18	Kent.......	32	7 N	12 W	1,997	Traverse	McCallum & Herr	20	First discovery in promising area
19	Allegan.....	24	3 N	13 W	1,754	Traverse	Claude Sutherland	25	Encouraging show
20	Van Buren..	11	1 S	15 W	1,174	Traverse	W. E. Ross	150	Discovery well, Columbia field
21	Van Buren..	14	1 S	14 W	1,277	Traverse	Little Four Oil Co.	300	Discovery well, Lake Mill field
22	Allegan.....	11	4 N	13 W	1,630	Traverse	Gordon Oil Co.	622	Important discovery
23	Clare.......	36	17 N	4 W	1,277	Stray-Marshall	Gulf Rfg. Co.	0[2]	Discovery well, Clare City field
24	Montcalm..	22	12 N	6 W	3,578	Dundee	Socony-Vacuum Oil Co.	0[3]	Discovery well, Home Twp. gas field
25	Clare.......	21	18 N	5 W	4,285	Monroe	Gulf Rfg. Co.	0[4]	
26	Montcalm..	7	12 N	9 W	1,134	Stray-Marshall	Taggart Bros. Inc.	0[5]	Stimulated development Winfield gas area
27	Monroe.....	28	8 S	6 E	2,512	St. Peters	Sun Oil Co.	0	First St. Peters test in area
28	Midland....	9	15 N	1 W	5,069	Sylvania	Sun Oil Co.	0	First Sylvania test in area
29	Midland....	27	14 N	2 E	5,195	Bass Island	Dow Chemical Co.	0	First Sylvania test in area

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1938	57	25
Number of oil wells completed during 1938	552	14
Number of gas wells completed during 1938	22	3
Number of dry holes completed during 1938	118	269

Surface formation, Pleistocene. [2] Gas, 14,200,000 cu. ft. [3] Gas, 4,900,000 cu. ft. [4] Gas, 20,000,000 cu. ft. [5] Gas, 1,120,000 cu. ft.

first well completed by the rotary method was drilled in the Temple field of Clare County. The well was completed at a depth of 3913 ft. in 27 days. The average combination rotary and cable drilling time is 40 days and straight cable drilling time averages 42 days in this field.

Proration and Crude Prices

The Temple field, Clare County, has been under proration almost since discovery. At first an allowable of 300 bbl. per well per day was agreed upon by field operators, but this was soon reduced by stages until at the end of the year 50 bbl. per well per day was agreed upon by the operators. Several price cuts during the first months of the field's development were responsible for the voluntary proration measures.

Prices fell during the year, particularly after the discovery of the Temple field and as production increased in the shallow pools of the southwestern counties. Midland grade dropped from $1.27 at the beginning of the year to 92½¢ in December. Other grades suffered corresponding cuts.

Acknowledgments

Mr. Carl C. Addison, Division Geologist of The Pure Oil Co., at Saginaw, Mich., and Mr. D. C. Shackelford, Chief Scout of that company, assisted in the preparation of tabulated data. The State Geological Survey of Michigan furnished production data on oil and gas and other information.

Oil and Gas Development in Mississippi during 1938

By H. M. Morse*

(New York Meeting, February, 1939)

There was little change in the oil and gas industry in Mississippi during the year 1938. No new fields were discovered and the production from the Amory field was nil. In the Jackson gas field six wells were drilled and production was obtained in each instance, but none of these wells increased the area from which the gas is produced.

Outside the Jackson gas field nine wells were drilled, of which details are given in the accompanying table.

The seeming lack of activity in Mississippi belied what was actually happening, for a great many geophysical crews of the major companies were active in all parts of the state. There were approximately 65 structures mapped and for the most part these have been leased. It is believed that 1939 will see an increase in wildcatting over a large part of the state.

Table 1.—*Summary of Drilling Operations in Mississippi*

Important Wildcats Drilled in 1938

	County	Location			Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Remarks
		Survey	Lat.	Long.					
1	Calhoun	9	22 N	9 E		Wilcox		Bill Young	Dry hole
2	Clarke	29	2 N	14 E		Jackson	Vicksburg	J. L. Ryan	Still drilling
3	George	9	1 S	8 W		Pleistocene	Selma, Up-Cre.	Ryan & Anderson	Dry hole
4	Hinds	35	6 N	4 W		Jackson	Trinity (?)	Cleve Love et al.	Dry hole
5	Hinds	26	7 N	4 W	3,448	Jackson	Wilcox	Geoffrey Jeffreys and E. R. Owen	Dry hole
6	Montgomery	30	20 N	7 E		No drilling, only permit issued			
7	Pontotoc	17	11 S	1 E		Wilcox	Ripley	Melvin & Waldrop	Dry hole
8	Wilkinson	35	4 N	1 W		Catahoula	Cockfield	La. Crusader Oil, Inc.	Dry hole
9	Yalobusha	24	18 S	6 W		Wilcox	Midway	Chas. W. Crader	Still drilling

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1938		2
Number of oil wells completed during 1938	None	None
Number of gas wells completed during 1938	6	
Number of dry holes completed during 1938		7

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Development of Oil and Gas in Missouri in 1938

By Frank C. Greene*

(New York Meeting, February, 1939)

The results of drilling in Missouri in 1938 are overshadowed by the leasing activity in northern Missouri, which began about the middle of the year. Nothing like it has ever been witnessed by the oil industry. With no production except a minor amount of gas, and with no drilling except in Clay, Platte and Marion Counties, a leasing campaign has embraced most of the counties north of the Missouri River and spread into southern Iowa, southeastern Nebraska and northeastern Kansas. It is reported that nearly all farms that could be leased without payment of a bonus have been leased, mostly on 10-yr. contracts, and at the end of the year a policy of bonus paying is in effect. Many of the major oil companies are leasing in the area and at least 15 of them are represented by scouts. Similarity to the Illinois Basin, low-priced leases and low drilling costs are among the reasons advanced for the leasing activity.

Drilling activity in Missouri increased nearly two-thirds over 1937, with a total of 164 completions. The main activity was the extension of the "shoestring" of the so-called Bartlesville gas pool in Jackson County. It now seems that this sand is probably at the horizon of the Burbank sand. A new Squirrel sand oil pool was discovered in Jackson County.

Cass County had five oil wells, with 63 bbl. initial production, four gas wells with 542,000 cu. ft. initial open flow, and 15 dry holes.

Jackson County had three oil wells, with 24 bbl. initial production, 56 gas wells with 52,021,168 cu. ft. initial open flow and 57 dry holes.

In Vernon County seven oil wells, with about 36 bbl. initial production, and two dry holes were completed. The oil production dropped off very quickly.

In counties where wildcatting was carried on, new production was found. Clay County had seven dry holes, Hickory and Marion one each; Platte, four and St. Clair, two.

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Oil and Gas Development in Montana during 1938

By Eugene S. Perry*

(New York Meeting, February, 1939)

The most notable development in oil and gas operations in Montana during 1938 were extensions to the Kevin-Sunburst and Cut Bank fields. No new fields were discovered, although about 20 widely scattered wildcat wells were operated. Within or adjacent to proved fields about 100 wells were drilled, resulting in 81 oil wells and 14 gas wells. In general, production activities were below those of 1937, largely because of market conditions. Markets for crude were improved late in the year by construction of refineries at Pocatello, Idaho, Spokane, Washington and Cut Bank; and also by price concessions. However, demand was much

Table 1.—*Oil and Gas Production in Montana*

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[a]	To End of 1938	During 1938
1	Baker-Glendive { *Fallon, Dawson* / *Wilbaux, Prairie* }	{ 23 gas / 3 oil }	x	134,350	15,801	3,363
2	Border (Red Coulee), *Toole*	8	300	0	Included with Kevin	
3	Bowdain-Saco, *Phillips Valley*	16	0	210,000	Gas only	
4	Bowes, *Blaine*	12	0	3,000	Gas only	
5	Boxelder, *Hill*	7	0	1,000	Gas only	
6	Cat Creek, *Petroleum (Garfield)*	18	1,600	0	13,743,877	211,877
7	Cut Bank, *Glacier*	9	38,000	55,000	13,123,000	2,830,551
8	Dry Creek, *Carbon*	9	200	1,800	1,201,374	330,352
9	Elk Basin, *Carbon* (Mont. only)[1]	23	200	y	759,904	7,230
10	Hardin, *Big Horn*	10	0	5,000	Gas only	
11	Kevin-Sunburst, *Toole*	16	45,000	50,000	{ Includes Border Field / 34,728,531	1,307,371
12	Lake Basin, *Stillwater*	11	300	1,000	384,072	18,462
13	Pondera, *Pondera, Teton*	10	4,500	0	5,061,342	217,044
14	Sweetgrass Hills (*Whitlash*), *Liberty, Toole*	21	500	8,000	48,234	9,417

[a] Footnotes to column heads and explanation of symbols are given on page 240.
[1] Elk Basin field in Wyoming, 138 completions, 91 oil wells, 7 gas wells.

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restricted, particularly for oil from the Kevin-Sunburst field, where at times it was as much as 50 per cent. Turner Valley oil (Canada) continued to flood northern Montana markets. Total oil production in Montana for 1938 was 4,939,439 bbl. and total gas production was 18,-025,000,000 cubic feet.

The extensions in the Kevin-Sunburst and Cut Bank fields were notable because they opened as proved or good prospective territory several thousand acres of land, and renewed interest in these two most important oil and gas fields of Montana. In the former field (Kevin-Sunburst) 31 wells with an average initial production of about 80 bbl. per day were completed 2 to 6 miles north and west of the town of Kevin, in an area long considered unimportant. Productive oil was found low on the western flank of the Sunburst dome, and apparently is controlled mainly by porosity within the leached and porous upper portion of the Madison (Mississippian) limestone. Acid treatment was responsible for most of the larger wells. Depth to limestone averaged 1600 ft., and Baumé gravity of oil is about 40°. Also significant in this general area is the finding of high-gravity oil in the Sunburst sand (Kootenai, Lower Cretaceous) which is about 300 ft. above the Madison, and which over about 95 per cent of the Kevin-Sunburst field yields only a dry gas.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					Oil-production Methods at End of 1938		Pressure, Lb. per Sq. In.[d]		
	To End of 1938	During 1938	Completed to End of 1938	During 1938		At End of 1938		Number of Wells		Initial	Average at End of	
				Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Flowing	Pumping		1937	1938
1	59,547	7,182	192	4	0	2	148	1	1		118 342	111 342
2	y	0	35	0	0	21	1	0	22		y	y
3	4,820y	734y	56	2	0	0	43			217	y	y
4	5,847	530					8	Gas only		260	y	y
5	1,720	277	4	1	1		2	Gas only		430	y	y
6	0	0	330	0	6	130	0	0	130			
7	47,991	7,714	480	36	0	355	61	6	349	710±	600	575y
8	5,524y	800y	14	0	0	8	6		8	1,600	y	y
9			33	0	1	22	0	0	22		y	y
10	581	72	29	1	2	0	27	Gas only		137	y	y
11	34,000y	2,398	2,401	41	11	1,161	168	0	1,161	360	gas 190 oil<100	gas 175 oil<100
12	Field use		40	0	4	3	1	0	2	300 1,000	y	y
13	Field use		185		0	159	2	0	159	200y		y
14	4,822	766	32	0	1	5	11	0	5	Col 275–330 Koot 600	y	y

These extensions open the possibility of other important extensions to this field in other directions.

In the Cut Bank field 20 wells with an average initial production slightly over 100 bbl. per day were completed in the so-called South Cut Bank area (Big Bend pool), materially adding to already proved territory. Average depth is 2800 ft. However, of much importance was the completion of a well flowing 85 bbl. per day about 12 miles north of the proved area, and about midway between the Cut Bank and Border fields. Oil was found in a sandstone slightly higher than the main Cut Bank sandstone (Kootenai, Lower Cretaceous) which yields oil in the fields to the north and south. Discovery of oil in this well opens a wide scope of territory.

Other oil and gas fields in Montana continued production without material change, and with but few completions, all in proved areas. Markets for the oil of the newly discovered deep eastern Montana field (Baker field) were unsteady. Attempts toward construction of a forty-million dollar, Government-financed gas pipe line to Minneapolis were not received with much enthusiasm by operators.

No outstanding wildcats were drilled, although several areas of possible production were tested, some by major companies. Two unsuc-

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1938	Producing Formation								Deepest Zone Tested to End of 1938	
	Gravity A.P.I. at 60° F.			Depth, Average in Feet							
	Weighted Average	Name	Age[e]	Bottoms of Productive Wells	To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
1	30	Gas Judith River Oil Madison(?)	CreU Mis	910 8,186	840 6,700	SH L	15 ?	70 20±	A	Devonian	8,186
2	37	Kootenai	CreL	2,520	2,500	S	14	12	T	Kootenai	2,600
3		Colorado	CreU	800	700	SH		25	D	Mississippian(?)	3,180
4		Eagle	CreU	1,100	1,000	S	16±	100	AF	Madison	4,700
5		Eagle	CreU	1,300	1,200	S	16±	100	A	Eagle	1,300
6	49	Kootenai	CreL	1,465	1,425	S	15±	40	AF	Madison (Mis)	4,124
7	38	Kootenai	CreL	2,850	2,830	S	13	12	ML MC	Madison	3,160
8	50	Gas Eagle Gas Frontier Oil Greybull Oil La Kota	CreU CreU CreL CreL	4,500 5,750	4,400 5,650	S S S S	50 30–75 15 40		AF	Tensleep (Pen)	6,887
9	43	Frontier	CreU	1,100	1,000	S	*y*	40	AF	Cloverly (CreL)	3,000
10		Colorado	CreU	745	725	SH		20	T	Tensleep	4,120
11	30	Gas Kootenai Oil Madison	CreL MisL	gas 1,220 oil 1,560	1,200 1,550	SH L	10–15 10–40	20 10	D	Pre-Cambrian	4,520
12	43.6	Gas Eagle Gas Frontier Oil Dakota	 CreU CreL	1,300 3,070 3,930	1,100 2,900 3,800	 S S	 *x*	100 40 30	D	Dakota (CreL)	4,100
13	31.0	Madison	MisL	2,020	2,000	L	10–30	10–30	N	Madison	2,500
14	36	Colorado Kootenai	CreU CreL	1,600–2,365		S S	12–18 14	20–30 25	D	Madison	2,205

cessful tests were made in the "steep-dip" structures just east of the front ranges of the Rockies. These structures are similar to those in the Turner Valley field.

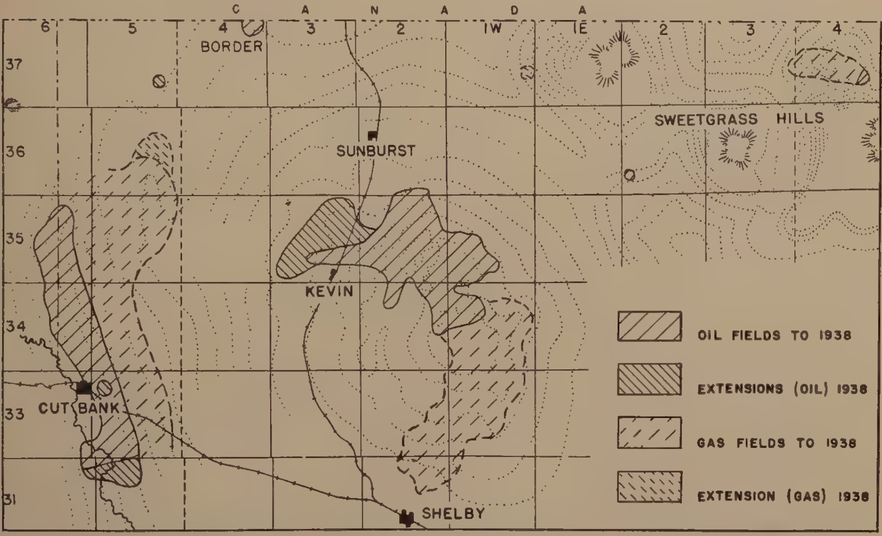

FIG. 1.—KEVIN-SUNBURST, CUT BANK, AND OTHER OIL AND GAS FIELDS IN NORTHERN MONTANA. DIAGRAMMATIC STRUCTURE CONTOURS DOTTED.

The year 1939 promises improved markets, and perhaps 150 new wells to be drilled in or adjacent to proved fields, largely because of lease requirements but also because of the newly discovered extensions. No doubt wildcatting will proceed with utmost precaution, and widespread wildcatting is not expected.

Oil and Gas Development in New Mexico in 1938

By A. Andreas*

New Mexico retained its position in 1938 as the sixth largest oil-producing state, with a total production of 35,510,176 bbl. This was 2,875,598 bbl. less than the 1937 production of 38,485,774 bbl., or a decrease of 0.077 per cent, which was caused by the lack of pipe-line facilities and storage at the pipe-line terminals.

The production for Lea County (excluding Maljamar) was 32,926,788 bbl.; for Eddy County (including Maljamar) was 2,225,411 bbl.; and for northwestern New Mexico (San Juan and McKinley Counties), 357,977 bbl. The average daily nonmarginal well allowable for Lea County on Jan. 1, 1938, was 65 bbl. At the close of the year it was 49 bbl. The average daily pipe-line runs for domestic consumption were less than the state allowables recommended by the United States Bureau of Mines. There was a demand for Artesia crude for foreign export, which if included in the daily production for New Mexico would be slightly in excess of the daily production recommended for New Mexico by the Bureau of Mines. The daily average production for the year was 97,329 barrels.

There were 622 completions in the state, of which 520 were oil wells; 16 hydrocarbon gas wells; 5 carbon dioxide gas wells, and 81 dry holes. Of the dry holes 38 were in or near-by proven fields and the remainder, 43, were wildcats. Five new fields were discovered in New Mexico during 1938, three in Lea County and two in Eddy County.

Southeastern New Mexico

Lea County.—The Monument field was the largest producing field in Lea County, with 9,440,334 bbl., and was closely followed by the Eunice field with 8,872,335 bbl. The Hobbs field was third with 5,010,414 bbl. The greatest activity in Lea County was in the Vacuum pool, with 129 completions, of which 126 were oil wells and three were dry holes.

The Texas Company completed its Corbin No. 1 in the NW¼ SW¼ sec. 10, T. 18 S., R. 33 E. in August. This well was drilled to a depth of 5118 ft. in a white sand, encountering salt water. It was plugged back to 4315 ft. and pumped 43 bbl. of 36° gravity oil in 12 hr. It was approximately 6 miles southwest of the closest production in the Vacuum

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pool and undoubtedly is a separate structure or producing area. The well has not produced any oil because of the lack of pipe-line facilities.

TABLE 1.—*Oil and Gas Production in New Mexico in* 1938

Line Number	Field, County	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					Oil-production Methods at End of 1938	
			Oil	Gas[a]	To End of 1938	During 1938	To End of 1938	During 1938	Completed to End of 1938	During 1938		At End of 1938		Number of Wells	
										Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Flowing	Artificial Lift
2	Artesia, *Eddy*	15	14,540*y*	2,960	11,405,116	2,135,402	*x*	*x*	490	68	*y*	323*y*	15*y*	75*y*	248*y*
2	Aztec, *San Juan*	14	90	5	33,729	3,600	0	0	29	1	1	16	0	0	16
3	Barber, *Eddy*	2	320	0	27,889	27,889	0	0	8	4	1	5	0	0	5
4	Black River, *Eddy*	1	80	0	2,872	2,728	0	0	2	1	1	1	0	0	1
5	Blanco, *San Juan*	11	0	40	1,286	60	195	29	1	0	1	0	1		
6	Comanche, *Chaves*	2	20	0	1,000*y*	*y*	0	0	1	0	0	1	0	0	1
7	Cooper, *Lea*	9	3,880*y*	160	9,529,467	1,682,178	74,470	22,757	101	9	*y*	95	2	52	43[1]
8	Eaves, *Lea*	9	720*y*	160	786,849	331,827	5,338.*y*	4,883	22	1	*y*	19	1	8	11[2]
9	Eunice, *Lea*	10	19,360*y*	160	32,471,511	8,872,335	127,576	44,720	488	45	*y*	483	0	447	36[3]
10	Getty, *Eddy*	10	240	0	341,806	59,392	0	0	9	0	*y*	4	0	0	4
11	Hardy, *Lea*	3	3,080*y*	0	1,005,063	620,268	4,623	3,875	79	39	*y*	75	0	67	8
12	Hobbs, *Lea*	10	10,080	0	85,543,485	5,010,414	186,114	11,438	266	1	*y*	252*y*	0	237	15[4]
13	Hogback, *San Juan*	16	160	0	1,882,256	73,231	0	0	7	0	0	7	0	7	0
14	Hospah, *McKinley*	11	120	0	10,000	1,000	0	0	5	2	0	0	0	0	0
15	Jal, *Lea*	11	1,360*y*	480	5,729,040	361,675	25,883.*y*	8,945	46	0	*y*	28*y*	12	16	12[5]
16	Kutz Canyon, *San Juan*	11	0	1,200	0	0	7,063	1,415	12	2	0	0	12		
17	Langlie, *Lea*	11	3,760*y*	320	2,015,370	1,219,006	14,171	10,732	106	46	0	98	8	96	2[6]
18	Lynch & N. Lynch, *Lea*	9	520	0	6,549,924	227,060	139.*y*	139	18	0	*y*	13	0	0	13
19	Lynn, *Lea*	9	1,000*y*	120	405,891	285,299	1,647	1,472	28	10	*y*	20*y*	3	16	4[7]
20	Mattix, *Lea*	2	3,360*y*	240	1,520,871	936,995	4,979	4,307	89	39	*y*	77	5	74	3
21	Monument, *Lea*	4	19,280*y*	40	24,203,434	9,440,344	68,216	28,773	482	18	*y*	478*y*	0	468	10
22	Penrose, *Lea*	3	5,320*y*	0	2,549,930	1,512,402	9,756	7,992	133	51	0	133	0	115	18[8]
23	Rattlesnake, *San Juan*	14	640	0	4,065,418	252,354	0	0	62	13	12	38	0	0	38
24	Red Mountain *McKinley*	3	20	0	3,700*y*	900*y*	0	0	7	1	0	2	0	0	2
25	Rhodes, *Lea*	11	240*y*	240	160,748	39,002	15,148.*y*	7,398	23	6	0	6	17	5	1
26	Skelly, *Lea*	3	2,080*y*	120	1,039,439	523,528	2,100.3	2,100	52	13	*y*	45*y*	1	30	15
27	South Eunice, *Lea*	9	2,680*y*	200	2,002,551	1,012,178	5,384.*y*	4,889	71	25	*y*	67*y*	0	66	1
28	South Lovington, *Lea*	1	0	40	0	0	*y*	*y*	1	1	0	0	1		
29	Table Mesa, *San Juan*	13	100	0	478,722	26,832	0	0	6	0	0	6	0	0	6
30	Ute Dome, *San Juan*	16	0	640	0	0	4,664	753	3	0	0	0	3		
31	Vacuum, *Lea*	10	5,240	0	858,429	850,703	936.*y*	936	131	126	0	129	0	122	7[9]
32	West Eunice, *Lea*	10	120	0	18,074*y*	1,574	0	0	3	2	0	2	0	0	2
33	Total		98,450*y*	7,085	194,643,870	35,510,176	558,402.3	167,553	2,780	524		2,423	81	1,901	524

[a] Footnotes to column heads and explanation of symbols are given on page 240.

[1] 22 pumping, 21 gas lift.
[2] 1 pumping, 10 gas lift.
[3] 12 pumping, 24 gas lift.
[4] 10 pumping, 5 gas lift.
[5] 8 pumping, 4 gas lift.
[6] 1 pumping, 1 gas lift.
[7] 3 pumping, 1 gas lift.
[8] 11 pumping, 7 gas lift.
[9] 6 pumping, 1 gas lift.

The Westmount Oil Co. completed its State No. 1 in December as a gas well in the NW¼ NE¼ sec. 12, T. 17 S., R. 36 E. Because of the lack of time and the closeness of the expiration date of the lease, which had to be validated by a commercial well, it was completed as a gas well

TABLE 1.—(*Continued*)

Line Number	Pressure Lb. per Sq. In.[d] Initial	Pressure Lb. per Sq. In.[d] Average at End of 1937	Pressure Lb. per Sq. In.[d] Average at End of 1938	Character of Oil, Approx. Average during 1938: Gravity A.P.I. at 60° F. Weighted Average	Producing Formation: Name	Producing Formation: Age[e]	Producing Formation: Depth, Average in Feet: Bottoms of Productive Wells	Producing Formation: Depth, Average in Feet: To Top of Productive Zone	Producing Formation: Character[f]	Producing Formation: Porosity[g]	Producing Formation: Net Thickness, Average in Feet	Producing Formation: Structure[h]	Deepest Zone Tested to End of 1938: Name	Deepest Zone Tested to End of 1938: Depth of Hole, Ft.	Reference to Text[i]
1	x	x	x	37.1	Upper San Andres	Per	3,693		D		x	Am	Permian	4,412	
2	x	x	x	55	Farmington sand	CreU	1,075	750	S		25	S	Lewis shale CreU	2,665	A
3	x	x	x	20.5	Capitan	Per	1,466	1,459	L		7	A	Capitan Per	1,953	
4	0	0	0	39	Delaware sand	Per	2,545		S			MF	Delaware	2,885	
5	e1,200	e1,100	e1,050	54	Pictured Cliffs	CreU	4,550	4,250	S		x	H	Mesa Verde CreU	4,550	A
6	0	0	0	y	Capitan	Per	1,283		S			ML	Capitan Per	1,400	
7	x	e1,250y	y	29	White Lime	Per	3,608	3,542	D	Cav	x	A	L. SanAndres Per	5,095	
8	x	e1,247	y	28.5	Permian sand	Per	3,300	3,175	S			A	San Andres Per	3,542	
9	x	e1,250y	y	34.0	White Lime	Per	3,883	3,800	D	Cav		A	San Andres Per	4,404	
10	0	0	0	22.y	Capitan	Per	1,380	1,365	L		15	A	Pennsylvanian?	6,683	
11	x	x	x	33	Permian sand and White Lime	Per	3,763	3,710	S-D	Cav		A	San Andres Per	3,821	
12	e1,550	e1,201	y	35.3	White Lime	Per	4,174	4,050	D	Cav	123	A	San Andres Per	4,500	
13	e215	e150	y	60	Dakota sand	CreU	714	705	S		9	D	McElmo CreL	1,225	A
14	x	x	x	29.7	Hospah sand	CreU	1,651	1,640	S		11	DF	Dakota CreU	3,282	A
15	y	y	y	36.0	White Lime	Per	3,334	3,303	D	Cav		A	San Andres Per	4,125	
16	e565	e480	e460		Pictured Cliffs	CreU	1,900	1,840	S		60	H	Mesa Verde CreU	4,400	A
17	x	e1,089	y	28	Permian sand	Per	3,530	3,350	S			A	San Andres Per	3,903	
18	x	0	0	27	White Lime	Per	3,777	3,760	D	Cav		AM	San Andres Per	4,046	
19	x	x	y	33	Permian sand and White Lime	Per	3,797	3,550	D	Cav		A	San Andres Per	5,095	
20	x	e1,200	y	29	Permian sand	Per	3,559	3,500	S			A	San Andres Per	4,200	
21	e1,427	e1,353	y	34	White Lime	Per	3,939	3,829	D	Cav		A	San Andres Per	4,534	
22	x	e1,000	y	36.5	Permian sand	Per	3,667	3,550	S			A	San Andres Per	4,705	
23	x	x	x	60	Dakota sand	CreU	808	784	S		24	AF	PenU	7,370	A
24	0	0	0	42	Mesa Verde	CreU	457	438	S		13	AF	Mesa Verde CreU	640	A
25	x	e1,278	y	38.8	Permian sand	Per	3,375	3,050	S			A	San Andres Per	4,115	
26	x	x	y	34	Permian sand	Per	3,663	3,525	S			A	San Andres Per	4,052	
27	x	e1,355	y	34	White Lime	Per	3,845	3,775	D	Cav		A	San Andres Per	6,202	
28					Capitan	Per	3,986	3,956	S			A	San Andres Per	3,986	
29	0	0	0	56.5	Dakota sand	CreU	1,337	1,325	S		7	A	Chinlee-TriassicU	3,010	A
30	e720	e525	e520	0	Dakota sand	CreU	2,350	2,285	S		60	D	Dakota CreU	2,350	A
31	e1,510	e1,510	e1,506y	35	White Lime	Per	4,688	4,418	D	Cav	200y	A	San Andres Per	5,329	
32	y		y	34.5	White Lime	Per	3,835	3,768	D	Cav		A	San Andres Per	4,695	
33															

at a depth of 3986 ft. The initial production was approximately 4½ million cubic feet. This gas well is approximately 7 miles northeast of the closest production in the Vacuum pool and undoubtedly is a new producing area.

The Wilson-State No. 1 in NE¼ sec. 7, T. 21 S., R. 35 E. was completed Oct. 10, 1938, estimated to be a 500-bbl. well. The total depth was 3813 ft., with the top of the pay horizon encountered at 3788 ft. The producing horizon is the San Andres formation of the Permian. This well was drilled approximately 1½ miles northeast from the Empire-State-B No. 1 in NW¼ sec. 8, T. 21 S., R. 35 E., which was completed on July 27, 1929, at a depth of 3836 ft., and which produced approximately 16,500 bbl. before being abandoned in 1934.

Eddy County.—Two new producing areas were discovered during the year in Eddy County; the first when the Shugart Coulthard No. 1 in

TABLE 2.—*Summary of Drilling Operations in New Mexico in* 1938

SURFACE FORMATION, TERTIARY; DEEPEST HORIZON TESTED, PERMIAN

Important Wildcats Drilled in 1938

	County	Location			Total Depth, Ft.	Drilled by	Initial Production per Day	
		Sec.	Twp.	Rge.			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.
1	Chaves	9	15 S	29 E	3680	English & Harmon	[1]	
2	Chaves	1	4 S	29 E	3686	Grastorff & Caudill	[1]	
3	Chaves	15	15 S	30 E	3982	Interstate Minerals	[1]	
4	Curry	13	2 N	31 E	3258	Bond & Harrison	[1]	
5	Eddy	35	18 S	31 E	4088 PB 3920	Shugart et al.	42[2]	
6	Eddy	15	25 S	28 E	3300	W. A. Snyder	[1]	
7	Eddy	31	19 S	27 E	1180 PB 960	M. Yates, Jr.	30[2]	
8	Eddy	35	18 S	30 E	3407	Yates & Dooley	[1]	
9	Harding	22	14 N	33 E	4445	Rip C. Underwood	[1]	
10	Lea	31	20 S	39 E	4355	Continental	[1]	
11	Lea	29	16 S	37 E	5303	Continental	[1]	
12	Lea	29	26 S	38 E	3707	Dalport Oil Corp.	[1]	
13	Lea	1	20 S	38 E	4757	Eastland Oil Co.	[1]	
14	Lea	29	25 S	38 E	3735	Leonard et al.	[1]	
15	Lea	20	22 S	33 E	5038	Mascho et al.	[1]	
16	Lea	22	10 S	37 E	5077	Rowan & Nichols	[1]	
17	Lea	33	18 S	36 E	5289	Shell	[1]	
18	Lea	10	18 S	33 E	5118 PB 4319	Texas	50[2]	
19	Lea	34	18 S	33 E	4295	Texas	[1]	
20	Lea	23	12 S	36 E	5294	Tidewater	[1]	
21	Lea	17	21 S	32 E	4608	Todd, et al.	[1]	
22	Lea	5	23 S	38 E	4500	Weiner, et al.	[1]	
23	Lea	12	17 S	36 E	3986	Westmount Oil Co.	[1]	4.46
24	Lea	7	21 S	35 E	3813	F. C. Wilson	500[2]	
25	Otero	34	22 S	13 E	3945	Fred Turner, Jr.	[1]	

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1938	129	33
Number of oil wells completed during 1938	516	4
Number of gas wells completed during 1938	15	1
Number of dry holes completed during 1938	38	43

[1] Dry and abandoned.
[2] Pumping.

sec. 35, T. 18 S., R. 31 E. was completed in May. This well was drilled to 4088 ft. and plugged back to 3920 ft. It was completed as a 42-bbl. pumper in the Capitan sand of Permian age. It is approximately 9 miles south of the Artesia-Grayburg-Jackson-Maljamar area. Since the completion of this discovery well, five other wells have been drilled to the same producing horizon.

The second new producing area was discovered by the completion of the Yates-Bowers No. 1 in sec. 31, T. 19 S., R. 27 E. late in December as a 30-bbl. pumper at a depth of 1180 ft. The producing horizon is in the Capitan formation of Permian age. The area is approximately eight miles southwest of the old Artesia field.

Northwestern New Mexico

Drilling in the northwestern part of New Mexico was confined chiefly to the Rattlesnake area, San Juan County. A number of dry holes were drilled in the Farmington district. In McKinley County development was on the Hospah dome, where commercial production was encountered in August 1927 by the Midwest Oil Co. The area is now being developed by the Petroleum Products Corporation. Two commercial oil wells were drilled on this structure in 1938, with an average initial production of 200 bbl. of low-sulphur oil of 30°. The producing horizon is the Hospah sand in the Upper Cretaceous. The producing horizon in the area is encountered around 1600 feet.

Northeastern New Mexico

In the Bueyeros field, northeastern New Mexico, in Harding County, four carbon dioxide gas wells were completed. In the extreme southeastern part of the county three wells were drilled, all of which were dry holes. Two were completed at shallow depths and the third, drilled in SW¼ sec. 22, T. 14 N., R. 33 E., first encountered arkose at a depth of 2800 ft., with sand, shale and limestone to 3540, where arkose was again encountered. It was reported that true granite was encountered around 4200 ft. The total depth of this well was 4445 feet.

Acknowledgments

The author is indebted to Mr. John A. Frost, District Engineer, United States Geological Survey, Farmington, New Mexico, for information on the northwestern area. Mr. C. G. Staley, Proration Umpire for Lea and Eddy Counties, furnished the information on oil and gas production. The various operating companies, particularly the Atlantic Oil and Refining Co., cooperated in furnishing general information. Mr. T. P. Wootton, of the staff of the State Bureau of Mines and Mineral Resources, Socorro, New Mexico, cooperated in furnishing general information and checking various data compiled by the Oil Conservation Commission.

Oil and Gas Developments in New York for 1938

By D. H. Newland,* Member A.I.M.E., and C. A. Hartnagel†

(New York Meeting, February, 1939)

The market for Pennsylvania grade showed a drop both in demand and in prices, which reacted unfavorably on New York oil production, all of which comes under that classification. The output for the year in New York amounted to 5,045,200 bbl. The production in 1937 was 5,478,000 bbl., the largest in any year for the last half century or more.

Falling prices, of course, affected new drilling. They declined from $2.20 a barrel, which was posted at the start, to $1.68 in the final months of 1938. With this came a reduction in the amount of oil that would be accepted by the refineries operating in the New York fields. Conditions therefore have combined to halt, at least temporarily, the growth of oil production in the state, which had experienced a steady gain for the last 15 years or more, the yield having risen from less than 1,000,000 bbl. to the round total of 5,500,000 bbl. in 1937.

Practically all the oil now obtained is from old, developed fields. No new pools have been found in the last quarter of a century or more. The larger share comes from flooding the sands. Although there are many wells that still produce without the aid of the water drive, they are small and for the most part are pumped periodically. Of late, new drilling has been restricted mainly to that required to maintain existing flood projects. Because of the high initial cost and time required to put a flood into production, the depressed condition of the market has been a serious handicap financially, and, further, has been an unfavorable influence on the planning of operations to secure the maximum recovery of the oil. Unless market conditions improve, it is certain that the effects will be shown in the yield for some time to come.

Gas Developments

Drilling was active in the southwestern area, chiefly in Allegany and Steuben Counties, and some notable wells were brought in that tapped the Oriskany sandstone. Altogether 42 holes were put down in the two counties, of which 31 were listed as producers and 11 were dry. The new wells gave an initial daily flow of 239,000 M cu. ft. At the close of

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the year there were 15 wells drilling in the two counties. Attempts to extend the productive area of the Oriskany sandstone to the east into Chemung County, along the Pennsylvania border, proved unsuccessful.

Allegany County.—One of the outstanding developments was the discovery last March of the Beech Hill pool, in the town of Willing, about 4 miles northeast of the State Line field. The new pool, like the State Line and the Greenwood gas fields, is on the Watkins (Smethport) anticline. The indications are that the field is not large, for 4 of the 11 wells drilled during the year produced only salt water. The combined daily initial capacity of the 7 producers thus far drilled in the field was 79,250 M cu. ft. Details of the wells are given in Table 1.

TABLE 1.—*Wells Drilled in* 1938 *in Beech Hill Field*

Name of Well	Reported Operator	Elevation, Ft.	Depth to Oriskany, Ft.	Flow, M Cu. Ft.	Rock Pressure, Lb. per Sq. In.
Johnson Estate........	Southwestern Development Co.	2,015	4,741	Salt water	
F. Hilligas No. 1......	Belmont	2,148	4,822	11,000	1,970
D. Clark No. 1........	Empire Gas & Fuel Co.	2,204	4,873	19,000	1,970
Riley Bros............	Becker	2,206	4,903	Salt water	
F. Wilson No. 1.......	Empire Gas & Fuel Co.	2,218	4,904	3,250	1,950
C. Wilson.............	Penn-York	2,200	4,900	1,700 With salt water	Abandoned
F. Hilligas No. 2......	Belmont......	2,231	4,924	11,000	1,905
G. Lampe.............	Belmont	2,229	4,935	25,000	Blew wild several days
Wm. Shear No. 1......	Cunningham	2,138	4,843	3,500	1,845
D. Clark No. 2........	Empire Gas & Fuel Co.	2,164	4,858	6,500	1,720
B. Fortner Estate......	Cunningham	2,268	4,997	Salt water	

In the State Line field three wells, all producers, were completed, having a combined initial daily capacity of 42,650 M cu. ft.; two in the town of Alma and the third in Willing, on the J. O'Hara farm, at an elevation of 1969 ft. The Oriskany was reached at a depth of 4727 ft. The daily initial capacity was 6150 M cu. ft. with a rock pressure of 1525 lb. The D. Mulvey well in Alma was drilled at an elevation of 2084 ft. The Oriskany was reached at a depth of 4746 ft. The initial flow was 18,500 M cu. ft. with a rock pressure of 860 lb. The Empire-Rogers well, also in the town of Alma, was started at an elevation of 2189 ft., reaching the Oriskany at a depth of 4906 ft. The well had an initial flow of 18,000 M cu. ft. and a rock pressure of 600 pounds.

In the town of Independence, between the Beech Hill and the Greenwood gas fields, two wells were drilled. One of these, the A. H. Billings, was started at an elevation of 2200 ft. and reached the Oriskany at a depth of 4915 ft. A flow of 150 M cu. ft. was found 3 ft. below the top of the Oriskany, but this was soon drowned out by salt water and the well was abandoned. The E. Livermore well, about 2 miles northeast of the Billings well, was started at an elevation of 2039 ft. Three feet below the top of the Oriskany, which was reached at 4751 ft., a flow of 13,000 M cu. ft. of gas was struck with a rock pressure of 1985 lb. At this depth salt water entered the well in such quantities that it was abandoned.

Steuben County.—In the Woodhull field 18 producers and two dry holes were drilled. The average initial daily capacity of the wells was 6341 M cu. ft. as compared with an average of 16,600 M cu. ft. for 20 consecutive wells drilled in the field during 1937. Withdrawals of gas from the field have been large, resulting in notable decreases in volumes and rock pressures during the year. The shooting of several wells in the northeast section of the field, where the sand is tight, has been successful in greatly increasing the flow of gas. At the end of 1938 six wells were in progress of drilling. Details of the wells are given in Table 2.

TABLE 2.—*Drilling Operations in the Woodhull Gas Field in* 1938

Name of Well	Reported Operator	Elevation, Ft.	Depth to Oriskany, Ft.	Flow, M Cu. Ft.	Rock Pressure, Lb. per Sq. In.
E. G. Husted	Sylvania	1,882	4,174	10,800	1,520
F. Miller	N. Y. State N. G.	1,805	4,209	10,500	1,760
E. G. Husted	Southwestern Dev. Co.	1,518	3,828	18,500	1,640
M. Hargraves	Clancy et al.	1,643	3,971	16,500	1,315
John Allen	Belmont Q. D.	1,809	4,159	9,000	1,280
Della Lampson	Williamsport Oil & Gas Co.	1,311	3,793	9,000	1,320
John Allen	Sylvania	1,773	4,107	9,500	1,370
Wheatcraft (Bates)	N. Y. State N. G.	1,445	3,880	4,200	1,620
Park Estate No. 1	N. Y. State N. G.	1,378	3,835	1,270	
H. Hand No. 2	Sylvania	1,651	3,901	4,700	795
C. Groves No. 2	G. L. Cabot	1,879	4,141	550	675
Neva Husted	G. L. Cabot	1,598	3,924	1,400	1,110
M. K. Husted	New Penn Dev. Co.	1,805	4,046	3,840	
Coral Cook	G. L. Cabot	1,954	4,421	Dry	
M. E. Woodard	Hanley & Bird	1,236	3,715	3,046	1,305
Don Gibson	G. L. Cabot	1,162	3,602	1,300	
Chas. Crane No. 1	G. L. Cabot	1,245	3,741	540	1,190
G. Hotaling No. 1	G. L. Cabot	1,281	3,762	2,000	600
Park Estate No. 2	N. Y. State N. G.	1,181	3,632	Dry	
Chas. Crane No. 2	G. L. Cabot	1,767	4,160	7,500	1,020

In Troupsburg township three wells were completed during the year, two of which, the A. Schaul and the S. Hammond, may be regarded as "step-out" wells of the Harrison field of Pennsylvania, as both are less than one mile from the state line. The Schaul well, completed early in January, was started at an elevation of 2058 ft. The top of the Oriskany was reached at a depth of 5010 ft. An initial daily flow of 796 M cu. ft. of gas with a rock pressure of 1935 lb. was found 9 ft. below the top of the Oriskany. The well was then deepened to 5026 ft., which increased the daily flow of gas to 2200 M cu. ft. The Sarah Hammond well is nearly 3 miles east of the Schaul well. The top of the well is at elevation of 2059 ft. and the Oriskany sandstone was reached at a depth of 5036 ft. A daily flow of 124 M cu. ft. was found at 5045 ft. The well was drilled to the base of the Oriskany sandstone at 5059 ft. and shot, after which the daily flow was increased to 200 M cubic feet.

The Franklin Miller well, also in Troupsburg, is 3 miles north of the Pennsylvania state line and close to the Woodhull town line. It was completed in January 1938 and had an initial daily capacity of 10,500 M cu. ft. of gas. This well extends the Woodhull field into the town of Troupsburg. Additional details of this well are given in Table 2.

In the town of Addison, 6 miles northeast of the Woodhull field, one well was completed on the D. Hovey farm. The top of the well is at an elevation of 1479 ft. and the top of the Oriskany at 3932 ft. The base of the Oriskany is logged at 3947 ft. with another sand streak at 3950 ft. The well reached a total depth of 4016 ft., but the Oriskany, which had a show of salt water, failed to produce any gas. In this well shallow gas was found at a depth of 1042 ft. (300 M) and at 1240 ft. (500 M).

Only one well was drilled during the year in the Greenwood gas field. This well is on the Caffery farm, 1 mile southwest of the nearest producing well. Starting from an elevation of 2072 ft., the Oriskany was reached at a depth of 4586 ft. On account of a large flow of salt water the well was abandoned at a depth of 4593 ft. At present two wells are being drilled in the Greenwood gas field.

In the town of West Union, 10 miles south of the Greenwood field, two Oriskany wells were completed during the year. One of these, the C. D. Carr well, is in the southeast corner of the town, less than ½ mile from the Pennsylvania state line. The well was started at an elevation of 2209 ft., and reached the top of the Oriskany sandstone at a depth of 5155 ft. It had an initial flow of 521 M cu. ft., which was increased to 850 M cu. ft. after the well was shot. The initial rock pressure was 1620 lb. In this well the Oriskany sandstone showed a thickness of 37 ft., the total depth of the well being 5198 ft. The Elmer Downey well is nearly 3 miles west of the Carr well and less than 300 ft. from the state line. The well was begun at an elevation of 2270 ft. and the top of the Oriskany sandstone was reached at a depth of 5317 ft. Salt water was

found in the Oriskany sandstone and the well was abandoned at a depth of 5327 ft.

Chemung County.—Two wells to test the Oriskany sandstone were drilled during the year. Thus far no successful tests of the Oriskany have been made in Chemung County, which lies east of the gas fields of Steuben County. The S. H. English well was drilled in the town of Van Etten within ½ mile of the Tioga County line. Drilled on the Van Etten anticline, the well was started at an elevation of 1284 ft. and the top of the Oriskany was found at a depth of 3222 ft. The sand, 70 ft. thick, was tight and dry, with no salt water in the Oriskany, although a considerable amount was found in a higher formation at a depth of 1010 ft. The total depth of the well was 3362 ft. The E. A. Treat well, in the town of Erin, is about 9 miles west-northwest of the English well. It was started at an elevation of 1663 ft. and the top of the Oriskany sandstone was found at a depth of 3431 ft. Salt water entered the well 24 ft. below the top of the Oriskany and drilling operations were suspended at a depth of 3447 ft., apparently before the full thickness of the Oriskany sandstone had been drilled. Of the seven tests to the Oriskany sandstone in Chemung County, none have produced any gas. The Treat well was the only one to produce salt water, and it is, in fact, the only one to give evidence of appreciable porosity for the Oriskany sandstone in Chemung County.

Cayuga County.—One deep well to test the lower Paleozoic formations was completed by the Midas Gas Corporation in the town of Conquest. The well is on the H. Slayton farm, near a well drilled in 1934, which yielded a considerable flow of gas at a depth of only 430 ft. Since no shallow gas was found in the second well, it was deepened to a total depth of 3863 ft. The top of the well is at an elevation of 475 ft. and was started on the Salina (Silurian) shales. The Lockport, or Niagara, dolomite was reached at a depth of 387 ft. and the top of the Medina sandstone at 800 ft. The Little Falls (Cambrian) dolomite was found at a depth of 3530 ft. and the top of the Potsdam sandstone at 3602 ft. The well was continued in the Potsdam for a distance of 261 ft. Only small flows of gas were obtained in the Ordovician formations. Some salt water was found in the Little Falls dolomite at a depth of 3560 ft. At 240 ft. below the top of the Potsdam sandstone, a large flow of salt water entered the well and rose to a height of 3000 ft. Efforts have been made to shut off the salt water and continue the well to the pre-Cambrian rocks, but as yet without success.

Oneida County.—Operations in Oneida County, where gas is obtained from the Trenton limestone, were limited to the drilling of one well in the Camden gas field. The well is on Comins property and was started at an elevation of 498 ft. The top of the Trenton was reached at 850 ft. and the well was completed in the Trenton at a depth of 1394 ft. Flows

of gas were found at several horizons in the Trenton, and when the well was closed in it showed a rock pressure of 380 lb. The initial flows and rock pressures of the Trenton wells are rarely indicative of the total volume of gas that may be obtained from a well. Pockets of gas frequently have high pressures but the volume is small. When the gas is derived from several horizons in the limestone, the well may produce for a period of 20 yr. or more. The annual flow, however, is not large.

Oil and Gas Development in Ohio for 1938

By Dewitt T. Ring,* Member A. I. M. E.

(New York Meeting, February, 1939)

Lack of reliable detailed production figures for earlier years, together with the loose nomenclature in reference to producing horizons and the application of the term "field" without any definite meaning or restriction, has made it impossible to gather statistical data suitable for the Institute's form.

In common with all other producing areas in the United States, Ohio has felt severely the economic ills of the entire industry during the past year. With overproduction, not only of crude but also of refined products, going on throughout the country, the price structure as a direct consequence has weakened on Ohio oils. Valuable crude is being sold at a big loss today because producers are willing to, and do, sell more than the market can absorb. The axe hangs heavy over the heads of Ohio producers, and will until something constructive is done to keep supply in proportion to demand. This not only applies to Ohio but to the entire industry.

Production of Pennsylvania grade in Ohio was under 50 per cent proration, which has been in effect since Oct. 1, 1937. Three price cuts since February have lowered the posted price from $1.70 to $1.18, a 30 per cent reduction; other grades were less drastically reduced. Pipeline storage facilities were limited; many producers were faced with the problem of providing their own storage or the risk of ruining their wells. If they wanted to pull and abandon wells, there was no market for junk equipment. Many employees have been cut to half time and in a number of instances their services entirely dispensed with.

Summary of Production and Drilling

Both oil and gas production in the state during 1938 showed a definite decline over the previous year. (A table showing production by years from 1876 through 1937 was published in Vol. 127 of the Transactions.) The total production of crude oil in the state for 1938 was 3,357,914 bbl., as compared with 3,654,000 bbl. in 1937, a decrease of 7.1 per cent. At

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the close of the year, as nearly as could be determined, there were 26,880 oil wells within the state, with an average yearly production of 125 bbl. per well—approximately ⅓ bbl. per day. Production by grades, for 1938, was as follows: Pennsylvania, 1,152,823 bbl.; Corning, 1,442,407 bbl.; Lima, 667,700 bbl.; Lodi, 82,680 bbl.; Cleveland, 12,304 bbl., making a grand total of 3,357,914 bbl. Prices are given in Table 1.

TABLE 1.—*Prices for Crude Oil in Ohio during the Year* 1938

Date	Grade	Price per Bbl.	Date	Grade	Price per Bbl.
Jan. 1–Mar. 7......	Pennsylvania	$1.70	Jan. 1–June 27........	Lodi	$1.25
Mar. 7–June 18....	Pennsylvania	1.55	June 27–Sept. 20......	Lodi	1.15
June 18–Sept. 1....	Pennsylvania	1.30	Sept. 20–Oct. 13......	Lodi	1.05
Sept. 1–Dec. 31....	Pennsylvania	1.18	Oct. 13–Dec. 31.......	Lodi	0.95
Jan. 1–June 16.....	Corning	1.27	Jan. 1–June 27........	Cleveland	1.30
June 16–Sept. 3....	Corning	1.17	June 27–Sept. 20......	Cleveland	1.20
Sept. 3–Oct. 18.....	Corning	1.07	Sept. 20–Oct. 13......	Cleveland	1.10
Oct. 18–Dec. 31....	Corning	0.97	Oct. 13–Dec. 31.......	Cleveland	1.00
Jan. 1–Oct. 13.....	Lima	1.00			
Oct. 13–Dec. 31....	Lima	0.90			

There were 189 oil wells completed during the year with a combined initial production of 4268 bbl., or 22.6 bbl. per well; this is 40 per cent less than the number of oil wells in 1937, also approximately the same percentage as the loss in total initial production.* Preliminary figures indicate that about 2025 oil wells were abandoned during the year, which compares closely with 1937. Over 900 wells were abandoned in the Lima field. The average production per well per day in that field was 0.19 bbl. The market price has been reduced to 90¢ per barrel. The field has about reached its economic limit of production based on the present price structure. More than a thousand wells were abandoned in the coal-bearing townships of eastern and southeastern Ohio.

During the year 433 gas wells were completed with a combined initial open flow of 198,970 M cu. ft. or 459 cu. ft. per well, a decline of 10 per cent in total open flow. Not included in the foregoing is 9186 cu. ft. of gas from old wells drilled deeper and casinghead gas wells, making a total of 208,156 M. cu. ft. for all new gas. The number of gas wells drilled in 1938 was 13.8 per cent less than in the preceding year.

There were 910 completions during the year; that is, 361 fewer than in 1937, or a decrease of 28.4 per cent. Included in the total completions were 288 dry holes, 163 less than in 1937, or a decrease of 36.1 per cent. The dry-hole percentage for the state was 31.6 per cent.

* The wells in Pennsylvania grade territory were completed as natural wells. After 50 per cent proration has been lifted, these wells will be "shot."

New Development

Few outstanding discoveries were made during the year; in most instances, they were extensions to present producing areas. Tables 2 and 3 present the completions according to sands and the initial volumes.

Table 2.—*Summary of Holes Drilled in Ohio in* 1938[a]

Sand	Thousands of Feet Drilled	Number of Gas Wells	Percentage of Total	Number of Oil Wells	Percentage of Total	Number of Dry Holes	Percentage of Total	Total
Shallow	248	106	42.4	58	21.2	86	34.4	250
Berea	373	150	47.5	63	19.9	103	32.6	316
Shale	17	16	76.2	1	4.8	4	19.0	21
Lime	13	13	100.0	0	0	0	0	13
Austinburg	6	2	66.6	0	0	1	33.3	3
Oriskany	23	0	0	4	80.0	1	20.0	5
Newburg	14	5	83.3	1	16.7	0	0	6
Clinton	862	134	51.2	55	21.0	73	27.9	262
Trenton	36	7	29.2	5	20.8	12	50.0	24
Sub-Trenton	20	0	0	2	20.0	8	80.0	10
Total	1,612	433	47.5	189	20.8	288	31.7	910

[a] Exclusive of deepening operations.

Table 3.—*Initial Volumes of Wells Drilled in Ohio in* 1938

Sand	Total Initial Volume		Average Initial Volume	
	M Cu. Ft.	Barrels	M Cu. Ft.	Barrels
Shallow	29,127	711	270	12
Berea	21,160	681	141	11
Shale	1,217	1	76	1
Lime	3,497	0	27	0
Austinburg	185	0	92	0
Oriskany	0	16	0	4
Newburg	5,272	3	1,054	3
Clinton	138,304	2,204	1,032	40
Trenton	208	152	30	30
Sub-Trenton	0	105	0	53
Total	198,970	4,268	124	23

Development

Oriskany Sand.—Further prospecting of the Oriskany sand in Ohio has assumed more importance during recent years. It is the reservoir rock of recently discovered gas fields of central New York, West Virginia

(Kanawha County), northern Pennsylvania and the Cambridge gas field in Ohio (1923).

In Ohio, the Oriskany formation has been found only in wells drilled in the eastern part of the state. Its geographic distribution is erratic and the formation is absent in large areas. The thickness varies from 1 to 75 ft., but is commonly 10 to 30 ft. In Ohio, the material is a fine-grained sand, loosely cemented with calcareous bond. It has been called the Austinburg, Guernsey County Lime sand, Cambridge Corniferous Lime sand, Niagara Lime sand, Lime sand, Sylvanian sandstone and Hillsboro sandstone in Ohio, and in West Virginia the Ridgely sandstone. Geologically, it lies at the base of the Corniferous or Columbus limestone and occurs from 50 to 240 ft. below the top of the Big Lime series of Ohio. This formation has been encountered by the drill at

TABLE 4.—*"Green-sand" Development in* 1938 *in Ohio*

Farm Name and Number	Operating Company	Sec.	Township	County	Production	
					Oil	Dry
A. M. Clouse No. 2	A. J. West	7	Clinton	Seneca	2½ bbl. per day	
A. M. Clouse No. 3	A. J. West	7	Clinton	Seneca		X
M. E. Crum No. 1	Sun Oil Co.	7	Clinton	Seneca	80 bbl. initial 12 bbl. Dec. 31	
F. J. Miller No. 1	Sun Oil Co.	7	Clinton	Seneca		X
J. Zeis No. 1	Sun Oil Co.	7	Clinton	Seneca		X
M. Hammer No. 1	Wicklund Development	22	Jackson	Seneca		X
Heimhofer No. 1	Sun Oil Co.		Allen	Hancock		X
Williams No. 5	Norton-Stewart Co.		Blanchard	Putnam		X
Peterson No. 1	Mid-West Development	19	Miami	Greene	½ bbl. A.S. Show gas	

1950 ft. in the Austinburg pool of Ashtabula County; at 3400 ft. in the Cambridge field of Guernsey County; at 4450 ft. in Madison township, Columbiana County; at 5200 ft. near Steubenville, Jefferson County; and at 5670 ft. in southeastern Washington County.

During the early part of 1938, Tyree et al., sec. 16, Sutton township, Meigs County, Ohio, encountered less than 8 in. of Oriskany with a slight show of gas at a depth of 3814 ft. At the close of the year, the Columbian Carbon Co. was drilling an Oriskany test on the George D. Miller farm, sec. 23, German township, Harrison County. This prospect is supposed to be on a geophysical "high". Another test by the same company is being drilled on the Ella Hammat, Grant district, Pleasants County, West Virginia. It is a short distance south of the Ohio River on the Burning Springs anticline; the results obtained will have a direct bearing on future prospecting of Oriskany sand in Washington County, Ohio. In Washington township, Tuscarawas County, one Oriskany test with a show of gas was abandoned at a depth of 3733 feet.

Newburg Sand.—In Mayfield township, Cuyahoga County, two gas wells were completed at a depth of 2860 ft., in the "Newburg sand," a dolomitic phase of the lower Niagaran, with open-flow capacities of approximately 300,000 cu. ft., and rock pressures of 1120 lb. After being treated with acid, the open flows were increased to 2,214,000 and 1,309,000 cu. ft., respectively. In Newburg township, Cuyahoga County. one Newburg well, which showed oil between 2572 and 2588 ft., was rated at 3 bbl. after being treated with 1000 gal. of acid.

TABLE 5.—*Summary of Wells Completed in* 1938, *Central and Southeastern Ohio Fields*

Country	Number of Completions	Number of Oil Wells	Production of Oil, Bbl.	Number of Gas Wells	Number of Dry Holes	County	Number of Completions	Number of Oil Wells	Production of Oil, Bbl.	Number of Gas Wells	Number of Dry Holes
Ashland	25	2	16	19	4	Mahoning	1	0	0	0	1
Ashtabula	5	0	0	3	2	Medina	30	11	264	3	16
Athens	76	7	81	41	28	Meigs	41	0	0	24	17
Belmont	13	1	4	7	5	Monroe	33	7	118	15	11
Carroll	11	4	28	0	7	Morgan	20	3	6	10	7
Columbiana	10	2	6	2	6	Muskingum	21	6	121	9	6
Coshocton	14	3	141	4	7	Noble	28	1	60	22	5
Cuyahoga	7	1	50	5	1	Perry	27	10	61	10	7
Delaware	1	0	0	0	1	Richland	3	0	0	1	2
Fairfield	14	0	0	10	4	Ross	1	0	0	0	1
Gallia	4	0	0	2	2	Scioto	2	0	0	1	1
Guernsey	56	1	5	35	20	Stark	29	0	0	24	5
Harrison	5	0	0	0	5	Summit	10	0	0	7	3
Hocking	2	1	5	1	0	Trumbull	1	0	0	0	1
Holmes	6	0	0	2	4	Tuscarawas	21	0	0	15	6
Huron	11	1	1	9	1	Vinton	6	0	0	5	1
Jackson	1	0	0	1	0	Washington	123	39	246	44	40
Jefferson	16	6	6	5	5	Wayne	7	0	0	4	3
Knox	57	19	1,028	28	10						
Lawrence	8	0	0	8	0	Total 1938	876	178	3,999	423	275
Licking	101	52	1,682	32	17	Total 1937	1,170	272	5,882	486	412
Lorain	29	1	70	15	13						
						Difference	− 294	− 94	−1,883	− 63	−137
						Percentage difference	25.1	32.0	32.0	33.2	13.0

Clinton Sand, Tuscarawas County.—In Franklin township, three Clinton gas wells and two dry holes were completed. The average depth was 4566 ft. and the rock pressures were greater than 1200 lb. Open flows ranged from 28,000 to 586,000 cu. ft. Two gas wells and one dry hole were completed in Sandy township. The average depth was 4822 ft., the rock pressure averaged 1300 lb. and the initial open flows were 1,300,000 and 1,770,000 cu. ft. Eight Clinton gas wells were completed in Lawrence township with open-flow capacities ranging from 60,000 to 8,283,000 cu. ft. and initial rock pressures from 1260 to 1350 lb. The average depth of the wells was 4660 ft. One Clinton gas well was completed in Dover township with a total depth of 4855 ft. and an initial

rock pressure of 1390 lb. The initial open flow was 2,400,000 cu. ft. In Jefferson township, one Clinton gas well was completed at a total depth of 4922 ft. The initial rock pressure was 1380 lb. and the initial open flow 967,000 cubic feet.

Sub-Trenton.—Considerable attention has been directed to exploration of the so-called "green sand" in the northwestern part of the state. In March 1938, A. J. West et al. completed the A. M. Clouse No. 2 in the southwest quarter of the northwest quarter of sec. 7, Clinton township, Seneca County. The total depth was 2059 ft.; the drilling samples

TABLE 6.—*Wells in Lima Fields*

County	Number of Completions	Number of Oil Wells	Production of Oil, Bbl.	Number of Gas Wells	Number of Dry Holes
Greene	1	1	2	0	0
Hancock	4	0	0	2	2
Putnam	6	5	127	0	1
Sandusky	2	0	0	1	1
Seneca	16	4	115	6	6
Wood	4	1	25	1	2
Wyandot	1	0	0	0	1
Total 1938	34	11	269	10	13
Total 1937	75	44	1,283	11	20
Difference	−41	−33	−1,014	− 1	− 7

of the sub-Trenton members were difficult to identify. The initial 24-hr. production was 40 bbl. Two days later the production had declined to 5 bbl.; it was later acidized without beneficial results.

A dry hole was drilled through the same horizon a short distance east of the No. 2 well. The Sun Oil Co., on June 28, completed the Mary E. Crum No. 1 in the southeast quarter of the southeast quarter of the northeast quarter, sec. 7, Clinton township, Seneca County, at a total depth of 2090 ft., or 28 ft. below the base of the Trenton lime. A show of oil in the Calciferous at 2074 to 2078 ft. was shot with 60 quarts and the bottom-hole water was plugged off. This well had an initial production of 80 bbl. per day. On Dec. 31 it was producing 12 bbl. per day. Analysis of the oil showed a gravity of 43° corrected to 60° F.; 0.48 per cent sulphur; 39 per cent gasoline of 16.6° gravity. Eight tests have been drilled during 1938 to the "green sand" in northwestern Ohio, but the Sun Oil Company's Crum No. 1 is the only well now producing. The other tests (except Clouse No. 2) were failures. Another test in sec. 19, Miami township, Greene County, drilled by the Mid-West Development Co., failed to produce.

As mentioned before, the characteristics and lithology of the so-called "green sand" are not sufficiently known to assign it definitely to its proper place in the geologic column of nomenclature. Whether it is a porous dolomitic phase of the basal Trenton or the upper part of the Lower Magnesian group called "Calciferous" by some geologists, and closely associated with the St. Peter sand horizon, remains to be determined. The writer has not examined any drill samples. The familiar Blue Lick water characteristic of the St. Peter sand in Ohio has been encountered in all nonproductive tests, either in or immediately below the "green sand" horizon. Sufficient data have not been assembled to determine whether porosity, structural deformation or stratigraphic changes control accumulation. The results thus far obtained from the number of tests drilled do not inspire enthusiasm but exploration no doubt will continue during 1939.

Repressuring

No new gas or air repressuring projects were started during the year. Five were in operation and another one will get under way in the eastern part of the state soon after the first of the year 1939.

An experiment in horizontal core drilling in the Cow Run sand near McConnellsville, Morgan County, is being tested in an effort to increase oil recovery. It is being done in an area where the oil-bearing sand outcrops. The project is supervised by Leo Ranney, pioneer in oil-mining methods.

Legislation

It is planned to submit a bill to the 1939 State Legislature which, if passed, would legalize water-flooding of oil sands. This method of secondary recovery in Ohio has potential possibilities, when the economic price structure improves sufficiently to justify such operations.

Acknowledgments

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Petroleum Development in Oklahoma in 1938

By H. E. Rorschach,* Member A.I.M.E.

(New York Meeting, February, 1939)

Activity in Oklahoma fields declined in 1938 from the banner year of 1937. During the year, 1768 wells were completed as compared to 2632 completed during the year 1937. The following tabulation sets out details regarding the wells completed during the year:

Wells	Oil Wells	Initial Production	Gas	Dry	Total
In defined pools..................	1,024	393,330	111	430	1,565
Wildcat..........................	27	17,660	26	150	203
	1,051	410,990	137	580	1,768

These computations do not take into account the wells drilled for repressure and salt-water disposal, and other nonexploratory wells. Purchasers' reports filed with the Corporation Commission of the State of Oklahoma show a total of 168,789,229 bbl. of oil purchased from Oklahoma leases in 1938, or a daily average of 462,436, a decrease of about 25 per cent from the year 1937.

The outstanding operation of the year was the further development of the Ramsey pool, in western Payne County, the producing horizon being classified as the Wilcox. This pool was discovered on the last day in the year 1937, by the Mid-Continent Petroleum Corporation drilling on a unitized block in sec. 18, T. 18 N., R. 2 E. The map in Fig. 1 shows the development at the end of the year 1938.

An important discovery of the year was the Champlin Refining Company's No. 1 Boehm, in Garfield County, sec. 4-24N-8W., the producing horizon being the second Wilcox found at a depth of approximately 6700 ft. This pool was assigned the name of Hillsdale. Some of the offsets to this discovery well had not come up to expectations at the end of the year, but the discovery seems to be important as indicating that the Wilcox sand is productive in the Anadarko Basin area, providing that the right structural conditions are present.

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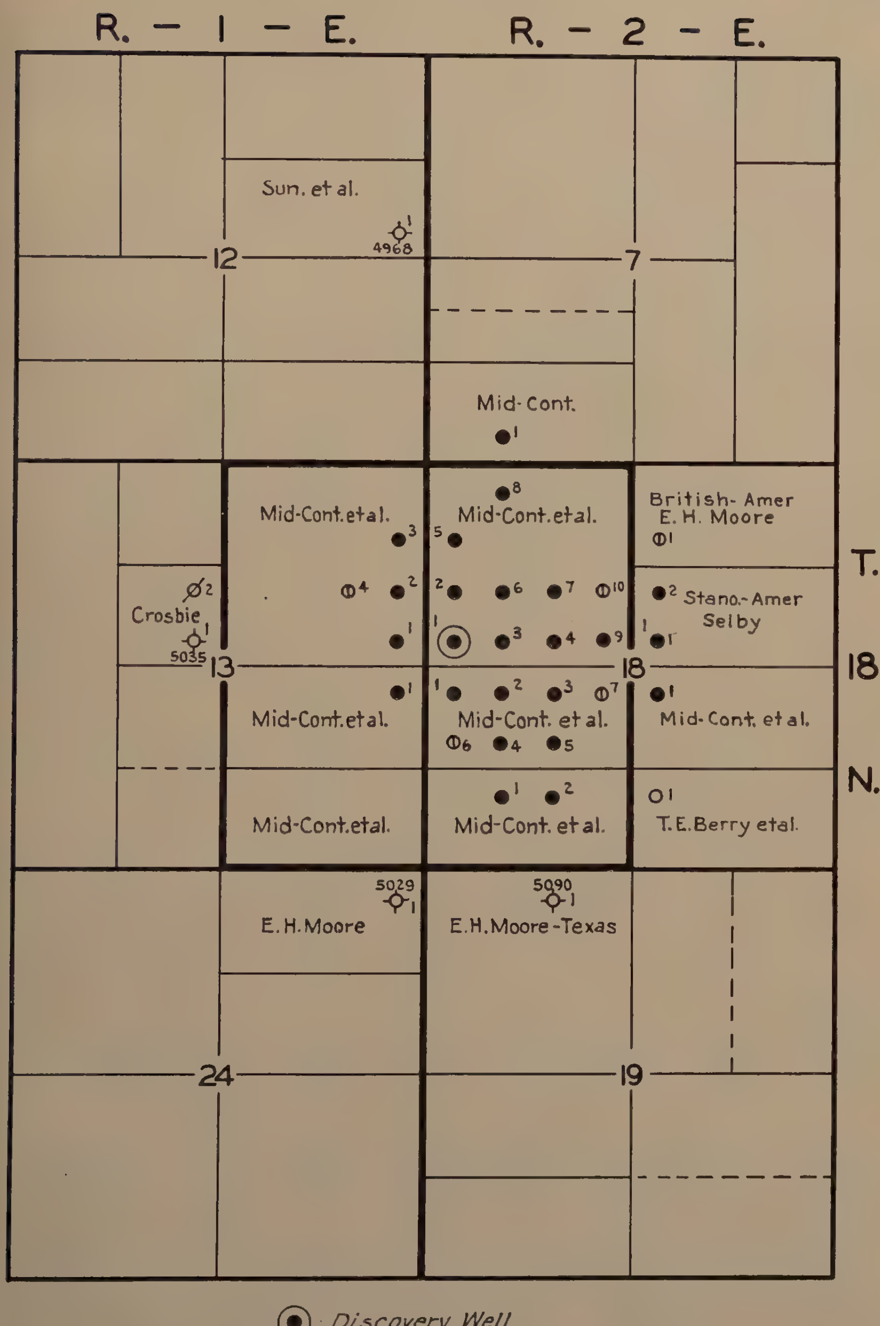

FIG. 1.—RAMSEY POOL, PAYNE COUNTY, OKLAHOMA.
Furnished by E. C. Jacobson.

Some of the other discoveries made during the year 1938 are the Hazel pool, producing from the Earlsboro sand, and the Konawa West pool, producing from the Senora sand, Seminole County, and the West Cement Extension in Caddo County. Table 2 lists the principal new oil areas discovered in Oklahoma in 1938.

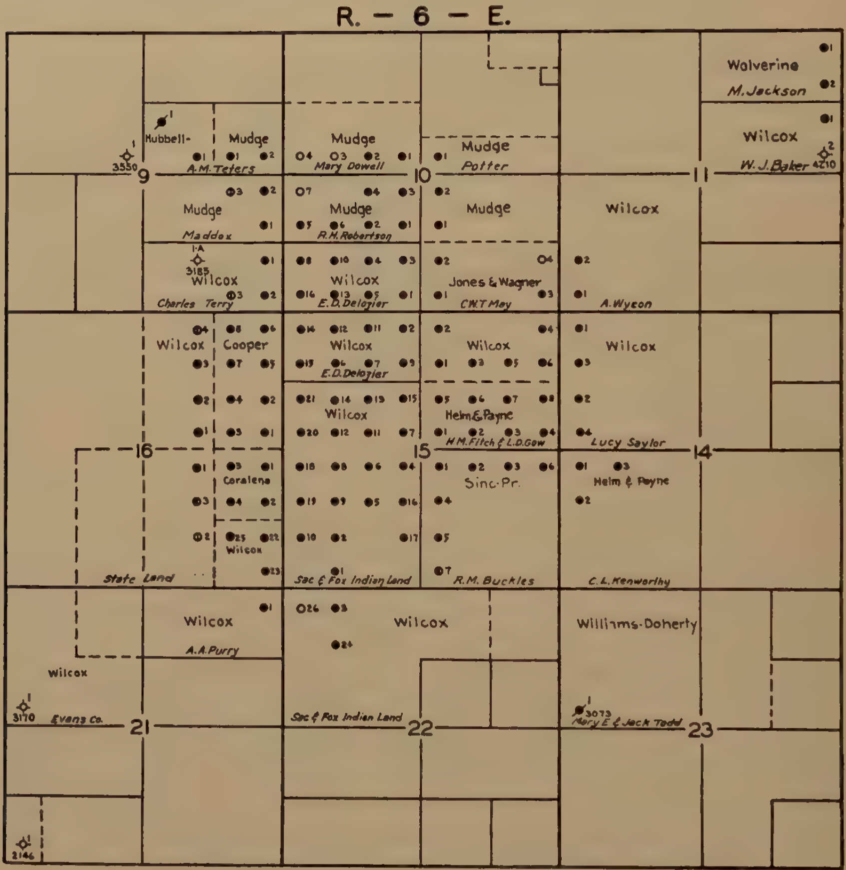

FIG. 2.—SAC AND FOX POOL, LINCOLN COUNTY, OKLAHOMA.
Furnished by E. C. Jacobson.

Fox-Milroy Area.—At the end of 1937 this area had indications of assuming considerable importance, but the development in 1938 has been rather disappointing.

Fitts Pool.—The Fitts area, Pontotoc County, was largely drilled up in 1937 and few new wells were completed in 1938.

Oklahoma City Pool.—Oklahoma City pool was fully outlined at the beginning of 1938; the activity during the year being largely confined to a few inside locations and the placing on the pump of most of the wells in the capitol extension area. Practically all of the wells in the field are

TABLE 1.—*Oil and Gas Production in Oklahoma in 1938*

Line Number	Field, *County*	Age, Years to End 1938	Area Proved, Acres: Oil	Area Proved, Acres: Gas[a]	Total Oil Production, Bbl.: To End of 1938	Total Oil Production, Bbl.: During 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	Number of Oil and/or Gas Wells: During 1938: Completed	Number of Oil and/or Gas Wells: During 1938: Abandoned	Number of Oil and/or Gas Wells: At End of 1938: Producing Oil[b]	Oil-production Methods at End of 1938, Number of Wells: Flowing	Oil-production Methods at End of 1938, Number of Wells: Pumping	Pressure, Lb. per Sq. In.[d]: Initial
1	Adams, *Hughes*	3	200		518,709	265,513	10	1	1	10	6	4	*e*1,500
2	Allen and West Allen, *Pontotoc*	25	300		44,424,741	2,212,643	320	59	15	300			
3	Altus, *Jackson*	5	490		630,179	147,875							
4	Asher-Wanette, *Pottawatomie*	9	675		6,965,687	120,428	37			40			
5	Bethel, *Seminole*	15	570		1,589,017	42,092							
6	Bethel, North, *Seminole*	2⅓	320		1,711,413	729,699	30			30	21	8	1,300
7	Billings, *Noble*	23	600	60									
8	Billings-Wilcox, *Noble*	3			4,480,561	2,042,410	62	6	1	61			*e*1,720
9	Binger, *Caddo*	5	10		46,496	9,840	1			1			
10	Bowlegs, *Seminole*	12	3,820		111,791,263	3,189,227	246	4	2	244			
11	Braman, North and South, *Kay*	15	1,095				125	4	1				
12	Britton, North, *Oklahoma*	4	100		452,484	106,892	9			9			2,000
13	Britton, South, *Oklahoma*	4	250		1,379,197	186,586	18			18			2,200
14	Brock, *Carter*	17	600		3,994,000	98,000	121			121			
15	Burbank, *Osage, Kay*	18	22,210	230	199,689,908	3,697,053	2,204			1,928			
16	Caldwell, *Grant*	10	30										
17	Carr City, *Seminole*	11	1,060		28,217,808	1,262,432	101		10			91	*e*320
18	Carter-Knox, *Grady-Stephens*	14	1,880	250	12,962,000	525,000	225			143			
19	Cement, *Caddo*	22	2,325		14,406,639	623,500	266	46	3	*y*			
20	Chandler, *Lincoln*	14	1,160		1,157,806	473,400	52			*y*			
21	Cleveland, *Pawnee*	35	9,720		55,307,709	650,215	*y*			*y*			
22	Crescent, *Logan*	6	1,010		11,077,954	1,650,800	47						*e*2,920
23	Cromwell, *Seminole*	16	4,790	130	54,025,674	1,216,000	498	6		277			
24	Cushing, *Creek*	27	23,528		334,583,969	2,848,237							
25	Davenport, *Lincoln*	13	2,000										
26	Deep Rock, *Payne*	14	520	80									
27	Dill, *Okfuskee*	5	700		1,826,541	399,520		1		21			
28	Dilworth, *Kay*	24	5,280	2,720									
29	Earlsboro, *Pottawatomie, Seminole*	13	6,890		122,816,130	1,750,826				213			
30	Earlsboro, East, *Seminole*	10	2,000		36,342,162	973,893	96						
	Earlsboro, North:												
31	Hunton, *Seminole*	3	160		232,853	68,113	11	6	1	10		4	*e*1,940
32	Wilcox, *Seminole*	2½	280		1,345,730	807,541	30	5		*y*		30	*e*1,365
33	Earlsboro, South, *Seminole*	9	300		8,414,427	230,931	30		1	19		19	*e* 350
34	Edmond, *Oklahoma*	9	1,120	20	13,665,225	2,009,450	96	2					*e*1,900
35	Fairfax, *Osage*	13								*y*			
	Fitts:												
36	Upper Simpson, Hunton, Gilcrease, Wilcox, and Cromwell sands, *Pontotoc*	5	4,280		73,834,125	16,316,791	455	32	4	421			*e*1,980
37	Oil Creek, *Pontotoc*	3	10		85,682	31,082				1			
38	West Fitts, *Pontotoc*	1½	170		221,322	157,719		11	2	20			*e*1,850
39	South Fitts, *Pontotoc*	1¾	320		107,906	44,303		1		12			
40	Fox, *Carter*	23	1,110	420	12,655,000	340,000	150			104			500
41	Fox-Simpson, *Carter*	4	600		737,966	485,266	2			2			
42	Garber, *Garfield*	23	3,840		49,708,313	600,458	873			582			
43	Gessman, *Lincoln*	5	110										
44	Glenn, *Creek*	34	14,720*y*										
45	Graham, *Carter*	21	2,520	220	25,575,000	475,000							750
46	Gray, *Pottawatomie*	7	180		3,493,806	336,173	28		2				*e*1,440
47	Grayson, *Seminole*	4	130		814,066	124,025	12	4	2				
48	Grisso, *Pottawatomie*	5			258,200	34,000	3					3	

[a] Footnotes to column heads and explanation of symbols are given on page 240.

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1938: Gravity A.P.I. at 60° F. Weighted Average	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zones	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
1	40	Hunton-Misener	Sil-Mis			Lime	P	15	A	Wilcox	4,317
2	30	Cromwell-Wilcox	Pen-Ord			S	Por	*y*	AF	*y*	*y*
3	43	Granite wash	Pen			S	Por	30	D		
4	43	*y*	*y*			*y*	*y*	*y*	*y*		
5	36	Booch	Pen			S	silty	27*y*	ML		
6	40	Cromwell	Pen	3,615	3,630	S	Por	20	A	Cromwell	
7	41	Hoover	Pen			S	Por	50	A		
8		Wilcox	Ord			S	Por		A		
9	41	Binger	Pen			S	Por	*y*	*y*		
10	40	Wilcox or Simpson	Ord			S	Por	30	A		
11	41	Various	Pen-Ord			SL	Por	*y*	A		
12	43	Simpson	Ord			D, L	Por		A		
13	43	Simpson	Ord			D, L	Por	50	AF		
14	35	Various	Pen	2,100		S	Por		AF	Ord lime	3,000
15	38	Burbank	Pen	2,850	2,700	S	Por	60	ML	Granite	4,240
16	44	Wilcox	Ord			S	Por	6	A		
17	40	Hunton-Wilcox	Pen-Ord	4,205	4,180	L-S	Por	*x*	A	Wilcox	4,210
18	35	Various	Per	2,200	1,700	S	15–20	15	AF		8,963
19	35	Caddo, Fortuna	Per-Pen			S	*y*	*y*	*y*		
20	40	Wilcox	Ord			S	Por	*x*	A		
21	37	Cleveland-Bartlesville	Pen			S	Por	*y*	*y*		
22	42	Layton-2nd Wilcox	Pen-Ord			S	23	*y*	AF		
23	35	Cromwell	Pen	3,400		S	Por	*x*	AF	Wilcox	4,226
24	40	Numerous Horizons	Pen-Ord			S, L	Por	*x*	AF		
25	46	Prue	Pen			S	Por	50	ML		
26	*y*	Wilcox-Bartlesville	Pen-Ord			S	Por	50	A		
27	40	Hunton-Cromwell	Sil Pen			S, L	Por	30	*y*		
28	40	Various	Pen-Ord, Per			S, SL	Por	*y*	A		
29	39	Earlsboro-Wilcox	Pen-Ord			*y*	*y*	*y*	*y*		
30	39	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*
31	40	Hunton	Sil			L			A	Wilcox	4,680
32	31	Wilcox	Ord	4,650	4,640	S	Por	10	A	Wilcox	4,680
33	40	Wilcox	Ord	4,225	4,200	S	Por	25	A	Wilcox	4,225
34	39	Wilcox	Ord	*y*	*y*	S	Por	*y*	AF	Arbuckle	7,000
35	38	Burbank	Pen			S	20–25	*y*	ML		
36	37.9	Oil Creek	Ord			S	Por	10	AF		
37		Bromide	Ord			S	Por				
38											
39		Cromwell	Pen			S	Por				
40	*y*	Deese	Pen	2,500	2,200	S	30	*x*	A		
41	30	Simpson	Ord	8,037	7,950	S	*x*	*x*	AF	Simpson	8,105
42	44	Various	Per-Pen-Ord	4,200	1,100	S, L	Por	*y*	AF	*y*	*y*
43	45	Cleveland	Pen			S	Por	*y*	M		
44	35	Glenn, Wilcox	Pen-Ord	*y*	*y*	S	Por	*y*	ML	Arbuckle	2,964
45	32	Deese	Lower Pen			S	28–30	45–70	A	Dornicks Hills	5,180
46	40	Wilcox	Ord	3,475	2,500	S	Por	25	A	Wilcox	3,500
47	40	Hunton, Simpson dolomite	Sil, Ord	4,050	4,030	SL	*y*	*y*	*y*	*y*	*y*
48	35	Hunton	Sil	4,050	4,030	L	*x*	*x*	A	Wilcox	4,860

TABLE 1.—(*Continued*)

Line Number	Field, County	Age, Years to End 1938	Area Proved, Acres		Total Oil Production, Bbl.		Number of Oil and/or Gas Wells				Oil-production Methods at End of 1938		Pressure, Lb. per Sq. In.[d]
			Oil	Gas[a]	To End of 1938	During 1938	Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Producing Oil[b]	Number of Wells: Flowing	Number of Wells: Pumping	Initial
49	Healdton, *Carter*	25	8,100		181,107,000	3,425,000		43	5				
50	Hewitt, *Carter*	20	3,450		84,934,000	1,520,000		6	3				
51	Hominy, *Osage*	19	300		1,911,924	12,250							
52	Hominy, East, *Osage*	18	450		1,952,237	21,125							
53	Hoyt, *Lincoln*	4			1,029,697	249,067	13	1	1				
54	Hubbard, *Kay*	15	620										
55	Hull, *Logan*	5	80										
56	Jesse, *Pontotoc*	4	1,360		2,145,139	704,985		21	2				
57	Josey, *Okfuskee*	16	300	10									
58	Keokuk Falls, *Seminole*	6	2,300		7,842,914	1,512,993	107	1					1,828
59	Keokuk Falls—Hunton, *Pottawatomie*	4			443,651	156,618	14			13			
60	Laffoon, *Lincoln*	6	60		1,167,250	221,250	8	4				8	*e*1,872
61	Langston, *Logan*	5	300		688,646	241,276	13	3	2		6	7	
62	Lincreek, *Lincoln-Creek*	23	160										
63	Little River, *Seminole*	12											
	and												
63*a*	Little River, East, *Seminole*	11	5,540		129,337,433	2,977,378	344	8	3	341			
64	Lovell, West, *Logan*	3	20		91,628	12,108				2			
	Lucien, *Noble:*												
65	East: Misener	4	10		171,687	29,887	1						
66	Viola	4	10		133,243	11,811	1						
67	North	3	250		342,529	197,524		4		8			*e*2,200
68	Lucien	6	2,660		19,513,282	3,261,087		3		121			
69	Marshall, *Logan*	12	1,940										1,950
70	Maud, *Pottawatomie-Seminole*	10	1,440		11,328,701	212,279	63		1			62	*e*1,000
71	Meeker, *Lincoln*	4	10										
72	Mission, *Seminole*	12			1,332,246	557,421	69			69			
73	Moore, *Cleveland*	4	1,060		6,186,385	1,753,035		2		39			
74	Naval Reserve, *Osage*	11	2,720	160	13,334,254	1,695,110	254			237			
75	Nicoma Park, *Oklahoma*	9	30		323,464	13,050	2			2			
	Oklahoma City, *Oklahoma:*												
76	Cleveland				1,543,045	525,000							
77	Wilcox	9	6,990		317,031,492	30,575,116	555	50	5				*e*2,600
78	Lower Simpson	10	10,000		102,395,609	5,477,194	226						*e*2,660
79	Pawhuska	10	190		978,403	793,598							
80	Other zones	10	1,610		19,276,451	971,659							
81	Upper Simpson	6	180		1,863,298	1,011,999	33						1,000
82	Olympic, Hughes, *Okfuskee*	5	4,400		7,385,066	1,290,457		2		221			
83	North Olympic, Hughes, *Okfuskee*	2	820		1,638,550	561,210				107			
84	Otoe City, *Noble*	8	10										
85	Ostott, *Kay*	21	3,300										
86	Papoose, Hughes, *Okfuskee*	15	2,400		23,701,000	261,000	77		16			61	
87	Pettit, *Osage*	19	380										
88	Polo, *Noble*	5	390		2,973,768	243,120	36			33			
89	Ponca City, *Kay*	28	1,670										
90	Ripley North, *Payne*	11	90										
91	Robberson, *Garvin*	18	1,480	320	13,370,000	475,000							
92	St. Louis, *Pottawatomie-Seminole*	13	8,240		119,004,974	7,769,300		169	28				600
93	Sasakwa, *Seminole*	11	560		7,999,647	232,417		4		40			
94	East Wilcox	4			886,627	218,378				7			
95	Townsite	6	120		1,954,024	158,435				8			
96	Searight	13	1,300		32,865,375	544,216				72			
97	Searight, North, *Seminole*	5	310		2,618,954	480,460				17			
98	Seminole, *Seminole*	13	4,150		128,558,443	3,455,718	330	9	1				
99	Seminole, West, *Seminole*	9	260		11,615,499	769,649	26		4	22		22	
100	Shawnee, *Pottawatomie*	5	640		1,230,682	401,706		4	2	24			500

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1938	Producing Formation								Deepest Zone Tested to End of 1938	
	Gravity A.P.I. at 60° F.			Depth, Average in Feet							
	Weighted Average	Name	Age[e]	Bottoms of Productive Wells	To Top of Productive Zones	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
49	31	Various	Pen-Ord	1,500		SL	Por	*x*	AF	Arbuckle	*x*
50	34	Hoxbar	Pen	1,700	*y*	S	15–20	50	AF	Arbuckle	*x*
51	37	Burgen, Siliceous lime	Ord	2,685	2,625	S, D	*x*	50	A	Arbuckle	3,206
52	34	Bartlesville	Pen	2,210	2,160	S	*x*	*y*	A	Arbuckle	2,857
53	41	1st Wilcox	Ord	5,100	*y*	S	Por	*y*	*y*	*y*	*y*
54	39	Various	Pen-Ord	*y*	*y*	SL	Por	*y*	AF	*y*	*y*
55	42	Layton	Pen	4,800	*y*	S	Por	*y*	*y*	*y*	*y*
56	41	McLish	Ord	4,633	4,621	S	Por	*y*	AF	*y*	*y*
57	41	Wilcox	Ord	3,650	3,600	S	*x*	50	D	Wilcox	3,700
58	40	Misener-Hunton	Mis, Sil	4,152	4,117	SL	*y*	15–20	A	Wilcox	4,483
59	41	Hunton	Sil			L	*y*	*y*	*y*		
60	22.5	Wilcox	Ord	4,275	4,190	S	Por	*x*	A	Wilcox	
61	40	Wilcox	Ord	5,145	5,100	S	Por	*x*	A	Wilcox	5,194
62	32	Wilcox	Ord			S	Por	*y*	*y*		
63	39	*y*	*y*			*y*	*y*	*y*	*y*		
63*a*	36	Cromwell-Wilcox	Pen-Ord			S	Por	*y*	*y*		
64	40	Wilcox	Ord			S	Por	*y*	*y*		
65	*y*	Misener	Mis			S	Por	*y*	*y*		
66	*y*	Viola	Ord			L	Por	*y*	*y*		
67	*y*	Wilcox	Ord			L-S	Por	*y*	*y*		
68	42	Wilcox	Ord			L-S	Por	*y*	*y*		
69	40	Various	Pen-Ord			S	Por	*y*	*y*		
70	39	Misener-Hunton	Mis. Sil	4,140	4,130	SL	Por	10	A	Wilcox	4,330
71	32	Wilcox	Ord			S	Por	6	*y*		
72	39	*y*	*y*			*y*	*y*	*y*	*y*		
73	47	2nd Wilcox	Ord			S	Por		A		
74	39	Burbank	Pen			S	*x*	*y*	*y*		
75	39	Trospex	Pen			S	Por	12	ML		
76											
		Cleveland				S					
77	39	Wilcox	Ord			S	22.5	*y*	*y*		
78	39	Lower Simpson	Ord			S	Por	*y*	*y*		
79	40	Pawhuska	Pen			L	Por	*y*	*y*		
80		Arbuckle	Cam Ord			L	Cav	*y*	*y*		
81		Misener	Pen			S	Por	*y*	*y*		
82											
	34	Senora-Colvin	Pen			S	Per	*y*	*y*		
83											
	34	Senora-Colvin	Pen			S	Por	*y*	*y*		
84		Layton	Pen			S	Por	*x*	*y*		
85	39	Stalmaker-Oswego	Pen			SL	*y*	*y*	*y*		
86	37	Cromwell	Pen			S	Por	10	A	Wilcox	
87		Simpson dol., sand	Ord			SD	Por	45	A	2nd Wilcox	
88	38	Various	Pen-Mis-Ord	4,900	4,823	S	*y*	*y*	*y*		
89											
90	43	Wilcox	Ord			S	Por	*y*	*y*		
91	28	Pontotoc-Simpson	Per-Ord			SL	*y*	*y*	A, AV		
92											
	39	Hunton-Simpson	Sil-Ord			LS	Por	*y*	*y*		
93	37	Cromwell-Wilcox	Pen-Ord			S	Por	*y*	*y*		
94	37	Wilcox	Ord			S	Por	*y*	*y*		
95	37	Wilcox	Ord			S	Por	*y*	*y*		
96	38	Hunton-Wilcox	Sil-Ord			SL	Por	*y*	*y*		
97	32	Wilcox	Ord			S	*y*	*y*	*y*		
98	39	Wilcox-(Simpson)	Ord			S	Por	*y*	*y*		
99	40	Wilcox	Ord	4,115	4,085	S	Por	30	A	Wilcox	4,150
100	34	Earlsboro	Pen			S	Por	*y*	*y*		

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End 1938	Area Proved, Acres: Oil	Area Proved, Acres: Gas[a]	Total Oil Production, Bbl.: To End of 1938	Total Oil Production, Bbl.: During 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	Number of Oil and/or Gas Wells: During 1938: Completed	Number of Oil and/or Gas Wells: During 1938: Abandoned	Number of Oil and/or Gas Wells: At End of 1938: Producing Oil[b]	Oil-production Methods at End of 1938, Number of Wells: Flowing	Oil-production Methods at End of 1938, Number of Wells: Pumping	Pressure, Lb. per Sq. In.[d]: Initial
101	Sholom Alechem, *Carter-Stephens*	15	4,180	220									760
102	Stillwater, *Payne*	4	120		465,000	54,020	6		2			4	*e*1,700
103	Tatum, *Carter*	12	2,230		16,105,200	845,200	1	4	3				500
104	Thomas, *Kay*	15	140										
105	Tipton, *Jackson*	4	330										
106	Tipton-Arbuckle, *Jackson*	3	280										
107	Tonkawa, *Kay, Noble*	18	2,300										
108	Tussy, *Garvin*	6	360										
109	Vernon, *Kay*	15	920										
110	Vines, *Murray*	19											
111	Watchorn, *Pawnee*	23	320										
112	Wewoka and Wewoka Townsite, *Seminole*	16	2,150										
113	Wheeler, *Carter*	23	540	160									300
114	Wilzetta and S. Wilzett, *Lincoln*	5	200		713,700	131,035	18	2				10	*e*1,977
115	Zimmerman, *Lincoln*	3	40										
116	Marathon, *Noble*	4											1,665
117	Dora, *Seminole*	2	970		2,120,593	1,769,667		1		20			
118	Fish-Cromwell, *Hughes, Seminole*	9			1,912,996	1,197,636		2	2	44			
119	Fish-Wilcox, *Hughes, Seminole*	5			6,130,844	750,000				33			
120	Milroy-Deep, *Stephens*	1⅓	40		197,121	103,569		1	1	1			
121	Shawnee-East, *Pottawatomie*	1½	100		41,491	28,629	2			1			
122	Shawnee-North, *Pottawatomie*	1⅓	100		41,108	14,792	1			1			
123	Sporn, *Lincoln*	2	80		402,380	188,199	9			9			
124	Tecumseh, *Pottawatomie*	1½	100		57,261	31,210	1			1			
125	Traugh, Deep, *Seminole*	1⅓	190		354,357	330,494	16						
126	Traugh, Shallow, *Seminole*	2	270		535,669	238,497	24	23	3				
127	Wellston-North, *Lincoln*	3	340		945,344	557,099	34	6					
128	Jesse Hunton, *Pontotoc*	5	900		491,006	320,714				18			
129	Konawa, *Seminole*	9	1,520		13,731,952	466,233	94	2	2				
130	Coyle, *Payne*	¼	40		18,389	18,389	1						
131	Avoca, *Pottawatomie*	½	50		30,066	30,066	4	1					
132	Meridian, *Logan*	½	20		22,156	22,156	1						
133	Tyrola, *Seminole*	1 mo.	30		7,320	7,320	1						
134	Ramsey, *Payne*	1	390		538,860	538,860	17	19	3				
135	Calvin, *Hughes*	1¾	80		38,554	38,554	1						
136	Centrahoma, *Coal*	2	80		30,594	24,963	2	1					
137	Citra, *Hughes*	1½	40		6,256	1,933	1						
138	Fream, *Hughes*	¾	20		8,485	8,485	2	1					
139	Hazel, *Seminole*	¾	190		103,442	103,442	14	6	1				
140	Hillsdale, *Garfield*	⅓	20		26,852	26,852	1						
141	West Konawa, *Seminole*	¾	100		106,670	106,670	9	13	5				
142	Lamont, *Grant*	1¼	20		207,216	142,698	2	3	2				
143	Noble, *Cleveland*		40		28,647	28,647	1						
144	Olsen, *Van Neck*	⅓	40		34,986	34,986	1						
145	Swan, *Seminole*	⅓	40		12,818	12,818	2	3	3				
146	Wankomis, *Garfield*	¾	40		19,504	19,504	1						
147	Britton, East, *Oklahoma*	⅔	40		14,141	14,141	1						
148	Cromwell, South, *Seminole*	1⅔	80		209,973	146,905							

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1938 — Gravity A.P.I. at 60° F. — Weighted Average	Producing Formation — Name	Producing Formation — Age[e]	Producing Formation — Depth, Average in Feet — Bottoms of Productive Wells	Producing Formation — Depth, Average in Feet — To Top of Productive Zones	Producing Formation — Character[f]	Producing Formation — Porosity[g]	Producing Formation — Net Thickness, Average in Feet	Producing Formation — Structure[h]	Deepest Zone Tested to End of 1938 — Name	Deepest Zone Tested to End of 1938 — Depth of Hole, Ft.
101											
	32	Deese	Pen			S	30	40	A		
102	40	Wilcox	Ord	4,306	4,300	S	Por	6	A	Wilcox	4,306
103	28	Deese-Dornick Hills	Pen			S	30	60	AMDL		
104	41	Various	Pen-Mis-Ord			SL	Por	*y*	*x*		
105	40	Not determined	?			L	Por	*y*	*x*		
106	40	*y*	*y*			*y*	*y*	*y*	*y*		
107	42	Various	Pen-Ord			S	Por	*y*	*x*		
108	26	Deese	Pen			S	Por	*y*	A		
109	40	Stalnaker	Mis			S		*y*	*x*		
110	*y*	Simpson	Ord			S	Por	*y*	*x*		
111	41	Wilcox-Layton	Ord-Pen			S	Por	*y*	*y*		
		y	*y*			*y*	*y*	*y*	*y*		
112	*y*	Cromwell-Hunton-Wilcox	Pen-Sil-Ord			SL	Por	*y*	*y*		
113	26	Pontotoc	Upper Pen			S	*y*		A		
114											
	39.7	Hunton	Sil	4,290	4,240	L	*x*	50	A	Wilcox	4,520
115	*y*	Hunton	Sil			L	*y*	20	*y*		
116	*y*	Wilcox	Ord			S	Por	34	A		
117											
118											
119											
120											
121											
122											
123											
124											
125						S					
126						S					
127		Wilcox				S					
128											
129											
130											
131											
132											
133											
134											
135											
136											
137											
138											
139											
140											
141											
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148											

being produced by (1) submersible electric centrifugal pumps, (2) gas lift, or (3) by using conventional rods and tubing. Table 3 indicates the production that has been secured from the various leases up to date, showing a total recovery of approximately 436,000,000 barrels.

Jesse Pool.—The Jesse pool, Pontotoc County, had several substantial producers completed during the year 1938. However, the pool appears to be definitely outlined and any additional developments will probably be the drilling of inside locations.

Greater Seminole Area.—Seminole County led the state of Oklahoma with 211 completions. Several small pools were opened during the year in the Seminole area, as follows: the Hazel, West Cromwell, Swan, and the Tyrola and the West Little River and an area that has been designated as the North Grayson pool in sec. 12-6N-5E. This last discovery was made by the Superior Oil Corporation; and the number of wells drilling at the end of 1938 seems to warrant the prediction that considerable recovery will be had from this area in 1939 from the dolomite found at a depth of approximately 3800 feet.

St. Louis Pool.—During the year 1938, one of the most active spots in Oklahoma was the St. Louis area in Pottawatomie County. The wells completed were principally extensions to the old St. Louis pool; however, several other producing horizons were opened by plug-backs or by deepening operations.

Cement Area.—About 40 wells were completed in the old Cement area in Caddo County during the year 1938. A 3500-bbl. well was completed opening up the western extension. Subsequent completions included some large gas wells from which the production exceeded one hundred million cubic feet daily.

Lincoln County.—The Sac and Fox pool in eastern Lincoln County made a comeback in the year 1938 (Fig. 2). Opened in January 1925 by the Wilcox Oil and Gas Co., only three wells were completed in that year, the field remaining dormant until the year 1938, when upward of 50 wells were drilled. Production is secured from the Prue sand from about 3000 ft. The initial production is not large, averaging around 100 bbl. daily, but the wells are comparatively cheap to drill and have a long life.

Southern Oklahoma.—The year 1938 saw very little activity in southern Oklahoma. Another zone in the Doyle pool, which was opened by Helmerich & Payne in 1937, was found to be productive.

Billings Pool.—Several additional wells were completed in the deep Wilcox horizon in the Billings pool for substantial 1938 production.

Water-flooding.—Water-flooding as a means of secondary recovery in the older oil fields in Oklahoma continued to increase in 1938 in Nowata, Rogers, and Washington County areas. During the year approximately 500 water-intake wells were drilled in eastern Oklahoma.

TABLE 2.—*New Oil Areas Discovered in Oklahoma in* 1938

Name of Pool	Location of Discovery Well	County	Company	Name of Well
Waukomis	34-21N-6W	Garfield	Waukomis Oil	Clark No. 1
Braman Southeast	16-28N-1W	Kay	Ohio	School land No. 1
Meridian	27-16N-1E	Logan	Sinclair	Crews No. 1
Coyle	12-17N-1E	Payne	Texas	Longan No. 1
Ramsey	18N-2E	Payne	Mid-Continent	Ramsey No. 1
Okfuskee	10-13N-10E	Okfuskee	Mid-Continent	Irelan No. 1
Noble	12-7N-2W	Cleveland	W. A. Delaney	Burgher No. 1
Calvin	8-5N-10E	Hughes	Phillips	Becker No. 1
Fream	29-9N-9E	Hughes	Amerada	Fream No. 1
Morrison	13-9N-10E	Hughes	Phillaine	Morrison No. 1
Cromwell North	26-11N-8E	Okfuskee	C. W. Titus	Lohmer No. 1
Hazel	35-7N-5E	Seminole	Villines	Reed No. 1
Konawa West	17-7N-6E	Seminole	Davis	Jones No. 1
Swan	18-6N-6E	Seminole	Delaney	Swan No. 1
Okla. City Ext	4-12N-3W	Oklahoma	Olson	Vanek No. 1
Hillsdale	4-24N-8W	Garfield	Champlin	Boehm No. 1
Britton, Ext	21-13N-3W	Oklahoma	Kerlyn	Orphanage No. 1
North Grayson	12-6N-5E	Seminole	Superior	Tiger No. 1
Tyrola	4-5N-6E	Seminole	Arch	Collins No. 1
Avoca	6-6N-4E	Pottawatomie	Atlantic	McCurrey No. 1
Little River West	17-7N-6E	Seminole	J. F. Smith	Edgeman No. 1
Cement Extension	27-6N-10W	Caddo	Ray Stephens	Griffin No. 2
Maud Pool	16-8N-5E	Pottawatomie	Morgan & Flynn	School land No. 1

Name of Pool	Date Completed	Initial Production in 24 Hr., Bbl.	Number of Wells 12-31-38	Producing Formation	Average Depth, Ft.	Accumulated Runs to Jan. 1, 1938, Bbl.
Waukomis	3- 7-38	250	1		7,336	19,504
Braman Southeast	7- 8-38	2,352	3	2nd Wilcox	3,645	27,735
Meridian	6-11-38	1,273	1	Wilcox	5,238	22,156
Coyle	5-22-38	1,145	2	Wilcox	4,965	18,389
Ramsey	1- 3-38	13,344	17	Wilcox	4,795	538,859
Okfuskee	2-16-38	100	4	Wilcox	3,431	38,148
Noble	5- 9-38	3,000	1	Dolomite	7,682	28,647
Calvin	4-20-38	6,804	1	Sand	6,286	38,629
Fream	4- 6-38	138	3	Wapanuka	3,348	8,503
Morrison	6-11-38	30	1	Viola	4,214	8,947
Cromwell North	8- 9-38	100	1	Sand	3,492	21,853
Hazel	6- 6-38	75	14	Earlsboro	2,999	103,442
Konawa West	3-14-35	40	10	Senora	2,307	105,585
Swan	5-10-38	60	2	Sand	2,693	12,818
Okla. City Ext	8-17-38	214	1	Upper Simp. Dolomite	6,776	34,986
Hillsdale	10- 1-38	510	2	Dolomite	6,703	18,012
Britton, Ext	9-26-38	250	1	Wilcox	6,707	14,141
North Grayson	11-27-38	810	1	Dolomite	3,794	11,096
Tyrola	11-30-38	2,500 Est.	1	Viola	3,270	12,417
Avoca	8-17-38	250	4	Viola	4,209	30,066
Little River West	9-14-38	800	5	Wilcox	4,380	48,606
Cement Extension	1- 6-38	3,348	No Report		4,361	
Maud Pool	11-10-38 Est.	3,580 Est.	1	Viola	4,145	23,603

Gas Repressuring.—More gas repressuring projects were being added to the already existing projects during the year 1938; approximately 125 wells were drilled for that purpose in northeastern Oklahoma. One of the large unitized blocks on which gas repressuring was being carried out in 1938 is in Avant district in central eastern Osage County. This formerly was a unitized project in which the Sinclair-Prairie Oil Co., Phillips Petroleum Co. and the Wolverine Petroleum Co. participated. At the end of the year, however, an exchange of property was affected whereby the Wolverine Petroleum Co. took over the project in its

TABLE 3.—*Oklahoma City Recoveries and Wells Drilled by Quarter Sections*

Quarter Section	Total Number Wells Drilled	Plug Back Upper Gas	Shut Down or Abnd.	Number Prod. Oil Wells	Estimated Recovery to Dec. 1, 1938, Bbl.	Estimated Average Recovery, Bbl.		October 1938 Production, Bbl.
						Per Well	Per Acre	
NE1-11-3	3	1	1	1	625,883	208,628	15,647	1,482
NW1-11-3	23		10	13	7,712,053	335,307	48,200	24,316
SW1-11-3	21	3	10	8	6,509,255	309,965	40,683	6,102
NE2-11-3	22	5	8	9	4,253,664	193,348	26,585	10,376
NW2-11-3	51	7	20	24	24,715,891	494,318	154,474	33,509
SE2-11-3	14	1	12	1	2,385,604	170,400	14,910	4,375
SW2-11-3	33	4	23	6	3,856,819	116,873	24,105	3,934
NE3-11-3	28		1	27	29,439,138	1,051,393	183,994	155,213
NW3-11-3	29		11	18	18,078,253	623,388	112,989	66,611
SE3-11-3	26	1	14	11	7,309,585	281,138	45,685	25,475
SW3-11-3	20		8	12	7,021,668	351,083	46,811	23,975
SE4-11-3	2		2		133,260	66,630	6,636	
NE10-11-3	29	1	7	21	15,339,311	528,942	95,871	46,395
NW10-11-13	39		14	25	15,921,326	408,239	99,508	68,735
SE10-11-3	24		10	14	9,390,191	391,257	58,689	26,856
SW10-11-3	21		6	15	7,114,462	338,784	54,727	36,048
NE11-11-3	14	3	5	6	2,020,929	144,352	12,631	5,423
NW11-11-3	8		6	2	606,683	75,835	3,792	
SE11-11-3	13	2	2	9	2,825,488	217,345	17,659	6,397
SW11-11-3	8		4	4	1,116,735	139,592	6,979	3,788
SE1 and all 12, 13 and 14-11-3	143	50	25	68	33,994,987	237,727	20,235	70,173
NE15-11-3	17		8	9	5,681,857	334,227	35,512	46,171
NW15-11-3	8			8	4,583,866	572,983	76,398	38,309
SE15-11-3	24		6	18	8,500,677	354,195	53,129	41,274
SW15-11-3	9			9	3,632,764	403,640	60,546	25,907
NE22-11-3	16		3	13	2,471,736	154,483	15,448	17,118
NW22-11-3	5			5	809,810	161,962	16,196	6,561
SE22-11-3	53		13	40	16,871,583	318,332	105,447	31,183
SW22-11-3	18		5	13	4,370,648	242,814	62,438	24,291
NE23-11-3	9		2	7	1,196,714	132,968	7,479	12,865
NW23-11-3	5		1	4	976,868	195,374	6,105	4,910
SE23-11-3	8			8	1,907,311	238,414	12,715	10,742
SW23-11-3	3	1		2	451,392	150,464	3,762	422
NE24-11-3	11	7	1	3	2,307,638	209,785	14,423	22,688
NW24-11-3	11	2		9	3,231,019	293,929	20,194	10,654
SE24-11-3	12	5	2	5	2,034,270	169,522	12,714	15,597
SW24-11-3	9			9	2,384,143	264,905	14,901	31,735
NE25-11-3	12	4		8	1,562,698	130,221	9,767	11,675
NW25-11-3	9			9	2,167,824	240,869	13,549	13,938
SE25-11-3	16		2	14	2,643,575	165,223	16,522	14,024
SW25-11-3	9			9	2,201,471	244,608	13,759	7,540
NE26-11-3	2			2	103,156	51,578	645	
NW26-11-3	9			9	4,196,456	466,273	26,228	34,904
SE26-11-3	5			5	2,459,261	491,852	16,395	564
SW26-11-3	8		2	6	1,988,935	248,617	15,299	10,585
NE27-11-3	13			13	3,962,908	304,839	39,629	19,801
NW27-11-3	1		1		91,913	91,913	9,191	
NE35-11-3	4			4	1,446,078	361,519	36,152	10,990
NW35-11-3	1			1	73,651	73,651	7,365	1,112
NE36-11-3	16		2	14	4,066,533	254,158	25,416	6,084
NW36-11-3	11		2	9	2,929,190	266,290	24,406	9,649
SE36-11-3	7		2	5	1,811,994	258,856	25,886	4,598

TABLE 3.—(*Continued*)

Quarter Section	Total Number Wells Drilled	Plug Back Upper Gas	Shut Down or Abnd.	Number Prod. Oil Wells	Estimated Recovery to Dec. 1, 1938, Bbl.	Estimated Average Recovery, Bbl. Per Well	Estimated Average Recovery, Bbl. Per Acre	October 1938 Production, Bbl.
SW36-11-3	3		1	2	1,013,310	337,770	33,777	394
SW7-11-2	2			2	272,962	136,481	13,648	7,110
NW18-11-2	4	3	1		18,894	4,723	472	
SE18-11-2	2		1	1	22,581	11,290	1,129	
SW18-11-2	8	2	4	2	1,364,060	170,507	17,050	
NE19-11-2	2		1	1	287,925	143,962	14,396	1,580
NW19-11-2	9	2	2	5	2,782,535	309,170	17,391	3,934
SE19-11-2	8	2	5	1	1,852,250	231,530	23,153	
SW19-11-2	10	5	2	3	1,971,394	197,139	12,322	119
SW29-11-2	2		2		14,209	7,104	710	
NE30-11-2	7	4		3	1,229,868	175,124	17,512	3,184
NW30-11-2	13	6	4	3	506,024	38,924	3,163	1,870
SE30-11-2	10	5	1	4	446,944	44,694	3,192	6,603
SW30-11-2	11		1	10	2,873,269	261,206	17,958	41,894
NE31-11-2	16		9	7	4,539,603	283,726	28,372	22,079
NW31-11-2	14		1	13	3,887,462	277,676	24,297	7,752
SE31-11-2	16		6	10	5,330,395	333,150	33,315	10,685
SW31-11-2	11		2	9	5,435,935	494,176	41,815	35,656
NW32-11-2	5	1	1	3	421,193	82,587	8,259	1,976
SW32-11-2	7		3	4	1,386,073	198,010	19,801	1,085
NE6-10-2	5		4	1	445,573	89,115	8,912	2,020
NW6-10-2	2		2		12,803	6,401	640	
SW14-12-3	1			1	92,537	92,537	4,627	11,006
NW15-12-3	5			5	79,057	15,811	1,581	12,666
SE15-12-3	19	4	3	12	1,914,946	100,786	11,968	19,671
SW15-12-3	31		1	30	1,570,870	50,670	9,818	24,884
NW16-12-3	3			3	83,595	27,865	2,090	9,864
NE22-12-3	32		5	27	7,136,090	223,000	44,600	127,319
NW22-12-3	2			2	102,457	51,228	3,415	2,449
SE22-12-3	36			36	13,883,296	385,647	86,771	235,298
SW22-12-3	10			10	2,354,514	235,451	39,242	58,820
NW23-12-3	9			9	1,822,359	202,484	30,372	56,677
SE23-12-3	1			1	271,957	271,957	6,799	2,779
SW23-12-3	20			20	8,339,576	416,979	69,496	133,600
NW26-12-3	23	3	9	11	2,280,648	99,158	17,543	6,704
NE27-12-3	13		1	12	3,655,683	281,206	22,848	85,986
NW27-12-3	9			9	2,057,879	228,653	34,298	67,861
SE27-12-3	25			25	4,853,128	194,125	30,332	175,345
NE34-12-3	27			27	8,897,617	329,541	59,317	168,909
SE34-12-3	38		2	36	29,181,444	767,933	182,384	238,718
SW34-12-3	12			12	5,617,171	468,097	56,172	62,091
NE35-12-3	9			9	618,928	68,769	7,737	22,997
NW35-12-3	7			7	559,729	79,961	13,990	15,950
SE35-12-3	10		1	9	2,934,108	293,411	29,341	19,643
SW35-12-3	14		1	13	3,506,963	250,497	25,050	7,317
NW36-12-3	3			3	1,547,307	515,769	51,577	22,946
SE36-12-3	1		1		6,409	6,409	641	
SW36-12-3	13	1	3	9	3,055,656	235,050	30,557	24,307
Total	1,452	135	331	986	436,024,310	300,292	34,575	2,952,710

entirety. During December 1938 the Osage Indian Agency notified all Burbank pool operators that all surplus casinghead gas must be returned to the Burbank sand. It is believed that this is the first Oklahoma pool in which any governmental agency has insisted upon steps being taken to maintain reservoir pressure.

South Burbank Unit Block.—This is one of the outstanding unitization plans being carried on in Oklahoma. This block comprises more than 2400 acres and includes most of the producing acreage on the South Burbank structure. Practically all of the surplus gas that accompanies the oil is reintroduced into the producing horizon through a series of key wells. Bottom-hole pressures have been maintained without any substantial decline for some time. At the end of 1938 the bottom-hole pressure was still over 600 lb. Approximately twenty-one million barrels of oil have been produced from the South Burbank area since its discovery in 1933, of which fifteen million barrels have been produced from the unitized area. Outside the unitized block 94 wells have been drilled, of which 64 were flowing and 30 were pumping at the end of the year 1938. The unitized block has eight gas-input wells and the properties lying outside of the block utilize 10 wells for gas output. Eighty-six wells are being produced on the unitized block and all are flowing with formation gas or reintroduced gas except eight wells that are being pumped mechanically—six by electric motors and two by gas pumps. During the year 1938 a rather careful detailed study was made comparing the wells pumped electrically with those pumped with gas engines. It appears from that study that the cost per net barrel is much less on the electrically equipped wells than those pumped by gas engines.

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Oil and Gas in Northern and Central Pennsylvania during 1938

By Arthur C. Simmons,* Member A.I.M.E.

The Pennsylvania-grade oil industry suffered a serious decline in 1938, which can be largely accounted for by the decrease in the use of lubricating oil. Production was considerably lower than in previous years and prices were very much lower. Operating profits undoubtedly were lower than the year 1933, for the average price of Bradford crude in 1938 was $1.898 as compared with $1.86 in 1933, and the difference in average price of $0.04 per barrel was more than offset by increased operating costs and taxes.

Bradford Field

Production in the Bradford field in the state of Pennsylvania averaged 36,759 bbl. per day in 1938 as compared with 41,300 bbl. in 1937. The decline in average daily production of 4541 bbl. can be attributed to low market price and pipe-line proration rather than to the actual physical capacity of the field. Pipe-line proration was in effect for the last eight months of the year and the daily average production per month fluctuated between a maximum of 41,852 bbl. per day in March 1938 and a minimum of 33,649 bbl. per day in November. Production figures for Bradford field have been corrected to include only the parts of the Bradford field that are within the state of Pennsylvania, but the well-completion data for the Bradford field cannot be segregated and include those of the entire Bradford field, part of which is in New York state.

Production from the Bradford field was obtained almost wholly by water-flooding and no radically new methods or practices occurred. Intensive research work was carried on both by individuals and companies and as a cooperative enterprise, and minor improvements are gradually occurring in spacing, shooting, application of pressure and water conditions.

Drilling

Central and Southern Pennsylvania.—Pennsylvania production in central and southern Pennsylvania was obtained largely by air and gas repressuring together with the usual amount of natural production, and the repressuring operations in other than the Bradford field have not

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materially increased the production. In 1938 the production was 10,983 bbl. per day as compared with 11,255 bbl. in 1937.

Completions in central and southern Pennsylvania totaled 392. Figures are not immediately available to compare the 1938 completions with those of 1937, but it appears probable that in 1938 the number of completions was considerably smaller than in 1937.

Bradford Field.—Well completions in the Bradford field, which include both wells drilled as producers and those drilled for water intake, totaled 2148 in 1938 as compared with 4112 in 1937.

TABLE 1.—*Oil Production, State of Pennsylvania,* 1938

Year	Bradford Field, Bbl.	Central and Southern Pennsylvania, Bbl.	State of Pennsylvania, Bbl.
1937 total	15,076,909	4,108,100	19,185,009
1938 total	13,417,102	4,008,923	17,426,025
Change	−1,659,807	−99,177	−1,758,984
1937 daily average	41,300	11,255	52,562
1938 daily average	36,759	10,983	47,742
Change	−4,541	−272	−4,820

Oil Price

Because of different posting schedules, there occurs a slight difference in the price of crude oil in the different Pennsylvania districts. The Bradford field prices are very slightly but uniformly higher. The year opened with Bradford crude selling at $2.20 and changes occurred downward on March 7 to $2.05, on June 13 to $1.80, and on Sept. 1 to $1.68. The price of $1.68 continued through the remainder of the year. There occurred a weighted average price of $1.898.

New Developments

Additional flowing wells were drilled in the Music Mountain field south and west of Bradford. There is indicated at the present time a producing area of only about 300 acres.

Oil and Gas Developments in Southwestern Pennsylvania during 1938

By John T. Galey,* Junior Member A.I.M.E.

(New York Meeting, February, 1939)

In southwestern Pennsylvania 151 wells[1] were completed during 1938, a total of 61 less than the preceding year. Of this number 81 were gas wells and 28 oil wells, which shows a considerable decline from 1937, when 108 gas wells and 64 oil wells were completed. However, 42 dry holes were drilled during 1938, which is two more than the previous year.

Shallow Development—Gas

No new extensions to old pools, or new wells that would indicate any substantial reserves, were found during the year. However, a number of commercial wells and many dry holes were drilled to the Big Injun sand in Menallen township, Fayette County. One well had an initial open flow of 6 million cu. ft. In Rich Hill township, Greene County, one well producing, from the Big Injun sand, 2 million cu. ft. was brought in. Several other gas wells were completed in Shaler township, Alleghany County and Center township, Greene County, both of which had initial open flows of 1 million cu. ft. from the 30-ft. sand. Another well, in Aleppo township, Greene County, had an equal volume from the Gordon Stray sand.

Oil

Development has proceeded at a retarded rate because of the low price of Pennsylvania-grade crude. A total initial of only 205 bbl., an average of 7.3 bbl. per well, was developed. This is 1785 bbl. less than during 1937 and no new repressuring operations have been contemplated to prevent the declining production. The average price received for oil was $1.56 per barrel, with a high of $1.88 and a low of $1.34. This oil costs $1.94 per barrel[2] to produce. The average price paid for Bradford

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[1] This figure includes both drilling and deepening of wells in the counties of Alleghany, Beaver, Greene and Washington; and parts of Fayette and Indiana.

[2] Includes cost of operation, general administrative expense, depletion, depreciation, drilling and other intangibles, and development costs.

oil was 34¢ higher and the cost of production 58¢ lower than southwestern Pennsylvania crude, while the average in West Virginia was 6¢ lower in selling price and cost 17¢ less per barrel to produce.

Deep-sand Drilling (*Table* 1).—Deep-sand drilling in southwestern Pennsylvania reached a new high during the year with 12 wells drilled to the Onondaga or Oriskany horizons (L. Dev.). Four of these were wildcats and only one of the four (P. Dunham) has had a show in the Onondaga. The Oriskany here has not been reached, but as the well is running very low structurally it offers slight possibility of being successful. The other three wildcats were failures. Four wells encountered gas in commercial volume in the Onondaga in the Summit pool, Fayette County,

TABLE 1.—*Summary of Deep Sand Drilling in Southern Pennsylvania in* 1938

County	Township	Well	Elevation, Ft.	Tully (Top), Ft.	Onondaga (Top), Ft.	Oriskany, Ft.	Total Depth, Ft.	Result
Alleghany	West Deer	Fred Backhaus	1,161	5,960	6,342	6,528–6,565	7,471	Dry
Armstrong	Wayne	Lowry Martin	1,585					Drilling
Beaver	S. Beaver	James Smith	925	4,167	4,338	4,552[1]	4,558	4 mm.
Beaver	S. Beaver	Eliz. Allen	1,153	4,415	4,566	4,770[1]	4,782	3.5 mm.
Beaver	S. Beaver	Funkhouser	1,208	4,497	4,660	4,856	4,863	Salt water
Fayette	S. Union	Heyn No. 2	2,464	6,105	6,657[1]		6,770	3.5 mm.
Fayette	S. Union	Indian Creek Coal & Coke	2,633	6,238	6,914[1]	7,103	7,161	1.1 mm.
Fayette	S. Union	Piedmont Coal	2,369	5,910	6,515[1]	6,709–6,804	6,825	2.6 mm.[2]
Fayette	N. Union	J. H. Sorg	2,580	6,400	6,925[1]	7,109[1]	7,119	2.3 mm.[3]
Fayette	Wharton	J. R. Thompson	2,542	6,760	7,360	7,556	8,159	Dry
Fayette	Spring Hill	P. Dunham	2,192	6,640	7,519			Fish[4] 7630 ft.
Washington	Mt. Pleasant	J. McBurney	1,282	6,190	6,475	6,695–6,789	7,050	Dry
Westmoreland	Penn	J. S. Marshall	1,180	6,980	7,480	7,647–7,753	7,777	Dry

[1] Producing horizon.
[2] Rock pressure 3045 lb.
[3] Rock pressure 2890 lb.
[4] 184 M and shows salt water.

and one of these showed more than 2 million cu. ft. of dry gas from the Oriskany. One well drilled by rotary and another by cable tools may have had a small volume of gas in the Oriskany. The fifth well drilled here, which is on the down-thrown side of the east flank fault, was dry. In the Blackhawk pool, Beaver County, three wells were completed, two of which proved to be commercial gassers in the Oriskany and the third, which is some distance down the east flank, proved to be a failure after encountering salt water.

The most important discoveries from a geological standpoint were made in the Piedmont Coal, J. H. Sorg, and J. S. Marshall wells. In the J. S. Marshall the Oriskany appeared to be highly metamorphosed, which is indicative of the fact that if Oriskany production is to be obtained on structures near the bottom of the basin some faulting must necessarily be present in close connection with the accumulation. The J. H. Sorg well, which produced the first commercial Oriskany gas outside Beaver County to be found in southwestern Pennsylvania, is in close proximity

to the east flank fault of the Chestnut Ridge anticline. The Onondaga limestone, which heretofore has been the only productive horizon here, was formerly considered to be porous only as a result of fracturing, but cores recently obtained indicate also the presence of small solution cavities, which should add materially to the porosity.

Rotary Drilling.—The rotary system of drilling in southwestern Pennsylvania was first employed this year in drilling the J. S. Marshall well, Penn township, Westmoreland County. Considerable difficulty was experienced with this method both here and also at the Fred Backhaus well, West Deer township, Alleghany County, because rock bits did not stand up in the hard rocks encountered. However, in the Piedmont Coal well this trouble was largely eliminated and drilling down to the Onondaga limestone was accomplished in rapid time. The cost of wells drilled to this horizon by the rotary method should be comparable to the cost of the cable-tool holes to the same horizon, and the drilling time much less. No difficulty on account of caving or explosive gas pockets should be experienced in the rotary method of drilling, all of which means that a deep test through the section from the Pittsburgh coal to the Onondaga limestone should be completed by rotary with little difficulty. However, as the Onondaga limestone causes such excessive wear on bits, the drilling cost through this formation is greatly increased. This increase is sufficient to make cable-tool drilling to the Oriskany less expensive, and since cementing technique employed on the caving Hamilton and Marcellus shales has been so greatly improved, and the cushioning of gas pockets by drilling them with a column of brine in the hole has worked so satisfactorily, wells drilled by the cable-tool method are not only less expensive but also fairly sure of reaching their objective. Thus the rotary system has been abandoned, temporarily at least, probably until it is necessary to attain greater speed in drilling to the Onondaga, at which time combination rigs will be used and cable tools employed to drill through the Onondaga limestone.

Exploratory Work.—Seismograph work has been done in a number of new areas in Alleghany, Armstrong, Beaver, Butler, Fayette and Westmoreland Counties and some results have apparently been obtained, as several large blocks of acreage are being held as a result of this work. One new deep test in Rochester township, Beaver County, is soon to be located on a seismograph high.

Pipe-line Activity.—The largest pipe-line project in recent years is under way in Greene and Fayette Counties, where the Carnegie Natural Gas Co. is building a line to bring gas from the Summit pool to connect with its existing lines near Waynesburg, Greene County. This line is approximately 27 miles of electrically welded 8-in. with a capacity of 25 million cu. ft. per day. It is notable that every modern method of construction is being employed in laying this line.

Prospect for 1939

Shallow oil development should be resumed when and if the price improves. Little untested acreage apparently remains to be drilled, but it seems possible that some opportunities for repressuring exist. The search for new gas reserves, particularly in the deep sands, should continue, depending upon the result shown by the Wayne township, Armstrong County, deep test and the attempts that will be made to extend the Summit pool in Fayette County, as it is generally believed that the present gas reserves are altogether inadequate to supply the demand in case of resumption of normal industrial activity. In this search for deep-sand gas, extensive surface and subsurface geological work should prove invaluable in selecting potentially productive areas. In fact, should a very small proportion of the expenditure made for geophysical work be expended for the former, some highly wished for results should be obtained.

Oil and Gas Developments in Tennessee in 1938

By Kendall E. Born,* Junior Member A.I.M.E.

(New York Meeting, February, 1939)

Production of crude oil in Tennessee during 1938 was slightly more than 41,000 bbl., an increase of about 5000 bbl. over 1937. The production by counties and by fields is shown in Table 1.

The increased production has resulted from continued activity in the Upper Cumberland district, especially in Clay County. The "Mississippi lime" production in Scott and Morgan Counties continued to show a further decline with a 1938 production of 12,379 bbl. as against 14,644 bbl. during 1937. Small scattered production from some half dozen wells in Clay, Pickett, and Fentress Counties, on which there are no accurate figures, is estimated at 500 bbl. during the year.

The only natural gas marketed off the lease in Tennessee during 1938 was in Morgan County, where a small amount was furnished for the town of Sunbright and immediate vicinity. The gas occurs with the oil in the Boone Camp field and small amounts were put on the line from the near-by Coon Hollow and Seabolt pools.

Developments

There were 88 wells spudded in during 1938, of which 10 were drilling or only temporarily shut down on Dec. 31, 1938. Eighty wells were completed during the year; 16 produced oil and 3 were gas wells of undetermined quantity. The total footage drilled on 1938 completions was 63,385 ft. Flush production during the year totaled 850 bbl. per day. The more important wildcats are listed in Table 2; the distribution of oil and gas tests drilled during the year, according to physiographic divisions, is given in Table 3.

Cumberland Plateau

There were no completions in the producing pools in Scott and Morgan Counties. The decline in production in these areas has been steady for the past several years. In an effort to revive production, present plans include a repressuring program in the Boone Camp field in Morgan County early in 1939. There was one completion in Morgan

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County. This test, drilled to 1720 ft., found gas in the Lower Mississippian, but the well was not commercial.

Detailed surface and subsurface studies have been carried on during the year by at least one major oil company in the northern part of the Cumberland Plateau. This general region will probably receive considerable attention during 1939. An active leasing campaign is under way.

Northeastern Highland Rim

As usual, the area of most active drilling operations during 1938 was the Upper Cumberland district, including Jackson, Clay, Pickett, and Fentress Counties. In this general region production is obtained at relatively shallow depths from the Trenton, Black River, and Stones River groups of limestones of the Middle Ordovician. In this district there were 69 completions with 14 oil producers and 3 undeveloped gas wells. The production from this district was 28,845 bbl., a gain of about 6000 bbl. over 1937.

Clay County.—Three new producing areas were discovered in Clay County during the year, two of which are west of the Cumberland River and represent the first commercial production in the western half of the county. During the spring of 1938, a test about 3 miles south of Celina found production in the Lebanon limestone at a depth of 452 ft. The initial was about 50 bbl. per day. Two other wells encountered pays below the Pencil Cave. At the end of the year five wells had been drilled in this field, three of which pumped 4000 bbl. in about 6 months. Production was found at 450 ft. in a test drilled in the Turkey Creek area, just north of Tinsleys Bottom. Production difficulties were encountered in

TABLE 1.—*Oil Production in Tennessee for* 1938

Line No.	Field, *County*	Age, Years to End of 1938	Production in 1937, Bbl.	Production in 1938, Bbl.	Number of Wells Pumped	Producing Formation				Structure[h]
						Name	Age[e]	Character[f]	Porosity[g]	
1	Glenmary, *Scott*	22	4,629	4,674	4	Glenmary	MisU	L	Fis	AF
2	Boone Camp, *Morgan*	14	1,860	1,392	12	Boone Camp	MisL	LS	Fis	T
3	Seabolt, *Morgan*	10	2,175	1,564	3	Boone Camp	MisL	LS	Fis	T
4	Coon Hollow, *Morgan*	9	5,980	5,749	4	Boone Camp	MisL	L	Fis	T
5	Beaty, *Fentress*	1½	1,*xxx*	1,*xxx*	1	Sunnybrook	Ord	L	Fis	D
6	Tinsleys Bottom, *Clay-Jackson*	14	2,005	100	2	Tinsleys Bottom	Ord	L	Fis	D
7	Jouett Creek, *Pickett*	12	530	1,100	2	Tinsleys Bottom	Ord	L	Fis	D
8	Pine Branch, *Clay*	1½	6,993	12,000	5	Tinsleys Bottom	Ord	L	Fis	D
9	Hargrove, *Clay*	2	10,250	1,250	4	Tinsleys Bottom	Ord	L	Fis	D
10	Goodpasture Bend, *Clay*	1½	500	7,300	2	Tinsleys Bottom	Ord	L	Fis	D
11	Irons Creek, *Clay*	11		640	1	Tinsleys Bottom	Ord	L	Fis	A
12	Arcott School, *Clay*	6 mo.		4,000	3	Tinsleys Bottom	Ord	L	Fis	D
13	Turkey Creek, *Clay*	6 mo.		400	1	Tinsleys Bottom	Ord	L	Fis	A
14	Celina, *Clay*	1 mo.		285	1	Sunnybrook	Ord	L	Fis	D
15	Lock Branch, *Jackson*	11		270	11	Tinsleys Bottom	Ord	L	Fis	D
16	Scattered, *Clay, Pickett, Fentress*		5*xx*	5*xx*	5	Tinsleys Bottom and Sunnybrook	Ord	L	Fis	A & D

[a] Footnotes to column heads and explanation of symbols are given on page 240.

this well and the total production for 1938 was only 400 bbl. In December, a 75-bbl. producer was drilled in just north of Celina. The production is from the Cannon limestone of the Trenton at a depth of 240 to 242 ft. This well has attracted considerable attention and since Jan. 1 three additional producers have been completed. Of the 46 completions in Clay County, 11 were producing wells.

Fentress County.—In the northwestern part of this county, a test well found small production at 614 ft. in the lower part of the Trenton. In all, there were seven completions in Fentress County, two of which are gas wells in an undeveloped gas area southwest of Jamestown. At the end of the year plans were under way to pipe the gas into Jamestown, the County seat.

Jackson County.—The only production in Jackson is in the Lock Branch field, where less than 300 bbl. was pumped during the year. There were nine completions in 1938, two of which tested the upper part of the Knox dolomite group. One new well in Tinsleys Bottom pumped about 30 bbl. before it was abandoned.

Pickett County.—One oil well was drilled in Pickett County in the old Jouett Creek field. Production, rated at 20 bbl. flush, was found at 540 to 545 ft. in the lower "Sunnybrook" pay near the base of the Hermitage formation. This well pumped 1100 bbl. during the year.

TABLE 2.—*Important Wildcat Tests Drilled in Tennessee during* 1938

Well Name	Well No.	County	Location	Drilled by	Total Depth, Ft.	Surface Formation	Deepest Formation Tested	Remarks
O. N. Cherry...	1	Clay	At Arcott school, 3 miles south of Celina	W. P. Clements et al.	663	Catheys (Ord)	Ridley (Ord)	Oil; 50 bbl. flush at 452 in Lebanon limestone; discovery well in Arcott field
Kyle & Vaughn.	1	Clay	¾ mile northwest of Celina	J. H. Overstreet et al.	242	Catheys (Ord)	Cannon (Ord)	Oil; 70 bbl. flush at 240 to 242 ft. in Cannon limestone
Donaldson Heirs	1	Clay	¾ mile northeast of Celina	Jesse Ashby et al.	1,456	Cannon (Ord)	Upper Canadian	No shows below base of the Trenton
R. V. Davidson.	1	Morgan	2 miles south of Deer Lodge	Messer et al.	1,720	Pen	Osage (Mis)	Gas shows in "Mississippi lime"
Clay Richardson	1	Jackson	Northeastern part of County; ½ mile northwest of Pleasant Hill school	Carter & Weil	1,702	Osage (Mis)	Upper Canadian	Black sulphur water in upper part of Knox dolomite group
Cinda Sells.....	1	Pickett	2½ miles northwest of Forbus	Jesse Ashby et al.	1,660	Osage (Mis)	Upper Canadian	No encouraging shows below the base of Trenton
Granville Cooper	1	Fentress	Above the mouth of Little Crab Creek, 6 miles west of Jamestown	H. A. Cotton et al.	1,710	Osage (Mis)	Upper Canadian	No oil shows below the Trenton; gas in the Stones River group
Henry Harrell...	1	Rutherford	Southeastern edge of Murfreesboro	Basin Oil & Gas Co.	651	Murfreesboro (Ord)	Upper Canadian	Fresh water in the upper part of the Knox dolomite group
J. S. Banks.....	1	Coffee	East-central part of county; 1 mile northeast of Noah	Edmund Dee et al.	1,022	Cannon (Ord)	Upper Canadian	Oil; small production in lower "Sunnybrook" at 110 to 120 ft.
Linda Morris...	1-C	Lake	Southern part of county at Madie	Henderson Oil Co.	3,130	Recent	Ordovician or Older?	Top of Paleozoic floor at 2,494 ft. (driller's log)

The well in northwestern Pickett County, reported last year,[1] which found saturation 1334 ft. below the base of the Chattanooga shale, has never been put on pump. This test, however, has been responsible for renewed interest in the deeper possibilities of the lower Ordovician in the Upper Cumberland district. During the year, seven wells were completed in the upper part of the Knox dolomite group of Canadian age. The objective of these wells was to test the so-called "St. Peter sand." Only shows of oil and gas were encountered. Recent detailed subsurface studies by the writer show definitely that the sandy horizons ("St. Peter sand") penetrated by some 50 wells throughout middle Tennessee are not zones with a definite stratigraphic position but rather represent sandy horizons in rocks of Canadian age. Although a rather widespread porosity for these arenaceous horizons has been proved by a number of oil and gas tests drilled in middle Tennessee, little definite information is available on its possibilities as an oil and gas producer. Very few of the test wells have been located with regard to structural conditions. Some 20 or 25 wells have reported good shows or have produced small amounts of oil from these horizons.

Middle Tennessee

There were eight completions in middle Tennessee during 1938, two of which were small producers. Late in the year, a test in northwestern Coffee County, on a structure previously mapped by this Division, encountered oil at 110 to 120 ft. in the Hermitage formation of the lower Trenton group. A second well near by was dry, but the third well entered the same pay at 107 to 114 ft. Both wells were treated with acid and are small producers of less than 5 bbl. each. No figures are available on this production for the year.

TABLE 3.—*Physiographic Distribution of Wells Drilled in Tennessee in* 1938

Physiographic Division	County	Wildcat	In Proven Fields	Oil Wells	Gas Wells
Cumberland Plateau	Morgan	1	0	0	0
Northeastern Highland Rim	Clay	34	12	11	1
	Jackson	8	1	1	0
	Pickett	6	2	1	0
	Fentress	5	1	1	2
Eastern Highland Rim	Warren	1	0	0	0
Northern Highland Rim	Sumner	3	0	0	0
Central Basin	Coffee	1	2	2	0
Western Valley	Perry	1	0	0	0
Mississippi Embayment	Lake	2	0	0	0

[1] K. E. Born: *Trans.* A.I.M.E. (1938) **127**, 499.

West Tennessee

In the Mississippi embayment of western Tennessee the Henderson Oil Company's Linda Morris 1-C, temporarily suspended in December 1937 at 3130 ft., was abandoned at this depth early in 1938. The driller logged the top of the Paleozoic floor at 2494 ft. The same company's Linda Morris 1-D was abandoned at 2452 ft. in the top of the Paleozoic group. A well just east of Tiptonville, at the south edge of Reelfoot Lake, is now drilling below 3100 ft. This test, which entered the Paleozoics at 2230 ft., is a particularly significant one since fossils have been found which permit a definite determination of the Paleozoics drilled to date. This information has not been officially released.

During the year, there has been a definite revival of interest in the oil and gas possibilities in the upper part of the Mississippi embayment. A considerable amount of geophysical work, both with magnetometer and seismograph, has been carried on in this region during the year. Some of this exploration has been followed by leasing, and as this paper goes to press several sizeable blocks of acreage have been recorded. The inquiries for data on this general area received by this Division point strongly toward considerable activity during 1939.

Acknowledgments

The writer acknowledges with thanks the assistance of Mr. H. B. Burwell, of the Tennessee Division of Geology, who collected many of the data used in this summary. It is also a pleasure to acknowledge the cooperation of the operators and drillers who have kindly furnished information.

Development and Production in East and East Central Texas for 1938

By D. V. Carter* and Franklin M. Hackbusch†

(New York Meeting, February, 1939)

Beginning the year 1938, the East and East Central Texas district comprised 48 counties, which is equivalent to the Texas Railroad Commission districts 5 and 6. At the close of the year there were 46 oil and gas fields in this district. Eight other fields, seven oil and one gas, have been abandoned.

Exploratory Drilling

During the year, 113 exploratory wells were drilled. Nine discoveries were made, five of which proved to be oil fields, three distillate, and one gas. Completions for the district were 2043 oil wells (distillate wells included), 36 gas wells and 163 dry holes. Exclusive of the East Texas field, the Marion County extension of the Rodessa field led the district in the number of completions during the year.

Production and Proration

All fields in the district produced a total of 182,369,484 bbl. of oil, a decrease of 12.57 per cent compared with the 208,594,453 bbl. produced during 1937. The East Texas field produced 148,189,913 bbl., which was 81.6 per cent of the district's production for 1938. November daily average oil production for the East and East Central district was 469,102 bbl. The estimated cumulative production to Jan. 1, 1939, for this district was 1,753,894,802 bbl. It is estimated that the East and East Central district produced 38.9 per cent of the state's total production for the year, which was 468,781,632 barrels.

The decrease in 1938 production, as compared to that of 1937, in this district was partly due to the Saturday and Sunday shutdowns, 71 days for the year, which is equivalent to 19.45 per cent of the year. All fields in this district were affected by shutdowns except the Texas portion of the Rodessa field, which was shut in only during January and February. Certain wells were exempt from these shutdowns because of special pro-

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ducing conditions or where wells furnished gas for domestic fuel purposes, but their weekly production was reduced in proportion when possible.

Table 3 gives the effective dates and the monthly average reservoir pressures, Saturday and Sunday shutdowns, and production by months for the year for the East Texas field, as reported by the Texas Railroad Commission.

The average reservoir pressure in December 1938 was 1109 lb., or 10 lb. under the pressure in December 1937, which is equivalent to a pressure decline in the order of 0.067 lb. per million barrels of reported oil produced. The average reservoir pressure for the year 1938 was 1117 pounds.

No material changes were made in the daily per well allowables for fields in this district except in the Talco and Sulphur Bluff fields, where the changes were as follows:

Field	Jan. 1	Mar. 1	Apr. 1	May 6	Aug. 1	Dec. 10	Dec. 31
Talco, barrels	46	50		53	52	65	
Sulphur Bluff, barrels	65	50	87		85		85

Discoveries and Extensions

The Navarro Crossing field, in northwest Houston County, is believed to be the most important oil discovery made in the district during the year. The discovery well, Humble Oil and Refining Company's No. 1 Dailey, J. L. Riviere survey, was drilled to a total depth of 5921 ft. and completed in the Woodbine sand at 5786 ft. Initial production was 296 bbl. of 45° gravity* oil per day on ¼-in. choke with a gas-oil ratio of 4420 to 1. At the end of the year approximately 500 acres were proved for oil production and approximately 2000 acres proved for gas.

The Collinsville field, Charles Quillan survey, Grayson County, was discovered by the Mildred Oil Co. when its No. 1 L. C. Netherly was drilled to a total depth of 4043 ft., plugged back and completed in the Strawn sand at 3868 ft. for an initial production of 269 bbl. of 29.3° gravity oil per day on pump.

J. R. Bunn et al., No. 1 J. H. Bowling, W. Walters survey, Cherokee County, was completed as the discovery well in the Lone Star field at a total depth of 4008 ft. in the Woodbine sand. The initial production was 86 bbl. of 35° gravity oil and 1000 M cu. ft. of gas per day on ⅜-in. choke—accompanied by a small quantity of salt water.

In the Talco field, Franklin and Titus Counties, the Magnolia Petroleum Co. completed its No. 3 J. A. Chapman, George Dyer survey, in the Paluxy sand, for an initial production of 210 bbl. of 21.2° gravity

* All oil gravities given in this paper are A.P.I.

oil, no water, per day on pump. This well represents an eastward extension of approximately ½ mile. Early in 1939, the Humble Oil and Refining Co. completed its No. 1 T. G. Temple in the Paluxy sand for an initial production of 399 bbl. of 18.66° gravity oil per day on pump, which further extended the eastern limits of the Talco field approximately ¼ mile.

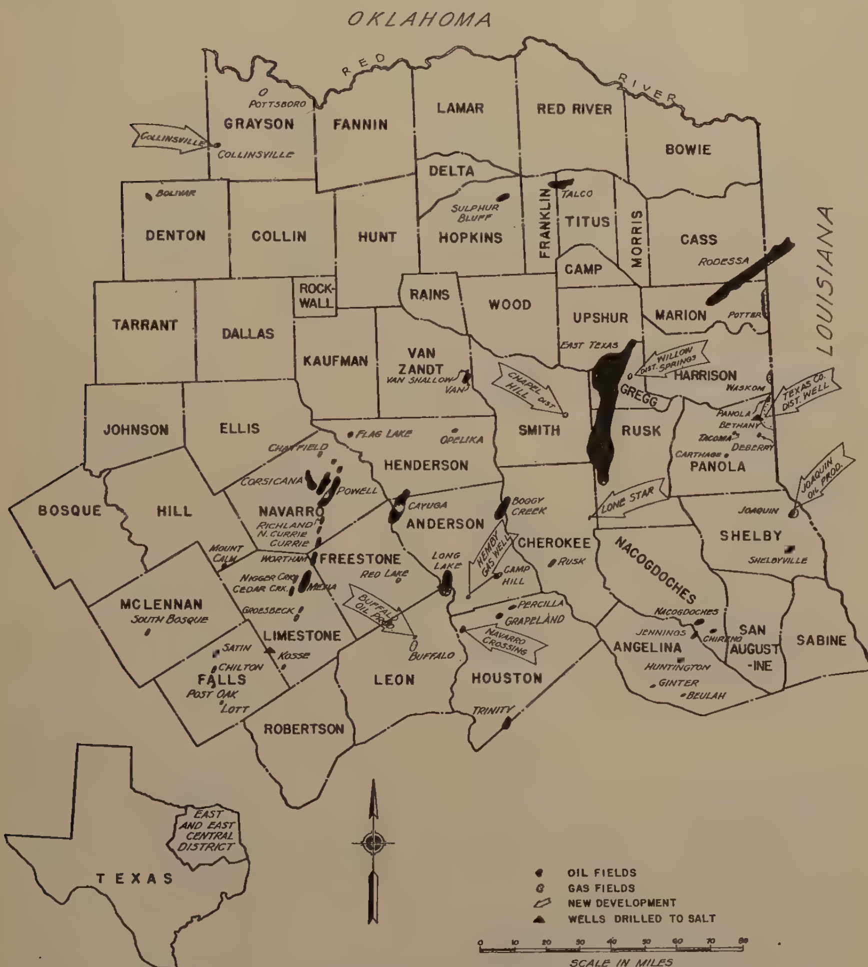

FIG. 1.—LOCATION OF OIL AND GAS FIELDS, EAST AND EAST CENTRAL TEXAS.

Bethany Area, Panola County, the Texas Company's No. 1-C, T. C. Adams, in the Thomas Cox survey, was drilled to a total depth of 11,303 ft. in salt, and after plugging back to 5735 ft. was completed as a distillate well in the Pettit limestone (Lower Glen Rose). Initial production was 358 bbl. of 62° gravity water-white distillate per day, accompanied by 17,900 M cu. ft. of gas per day through 2½-in. open tubing.

TABLE 1.—*Oil and Gas Production in East and East Central Texas*

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[a]	To End of 1938	During 1938	To End of 1938	During 1938
1	Bolivar, *Denton*	1937	600	200	3,922	2,282	*y*	*y*
2	Boggy Creek, *Cherokee*	1927	960	0	4,670,258	121,093	*y*	*y*
3	Bosque, South; *McLennan*	1902	2,500	0	96,754	3,865	0	0
4	Buffalo, *Leon*	1934	10	0	2,783	2,783	*y*	*y*
5	Carthage,[1] *Panola*	1936	1,000	0	25,526	10,273	1,692	595
6	Cayuga, *Anderson and Henderson*	1934	4,000	9,000	10,263,866	3,110,362	34,390	6,667
7	Chapel Hill,[1] *Smith*	1938	*x*	*x*	14,642	14,642	257	257
8	Collinsville,[2] *Grayson*	1938	100	0	12,064	8,648	*y*	*y*
9	Corsicana,[3] *Navarro*	1895	6,710	0	13,908,929	152,803	*x*	*x*
10	Currie,[4] *Navarro*	1921	475	0	6,789,814	37,285	*x*	*x*
11	East Texas, *Cherokee, Gregg, Rusk, Smith, Upshur*	1930	136,000	2,000	1,300,457,160	148,189,913	*x*	*x*
12	Flag Lake, *Henderson*	1937	1,280	0	137,959	133,920	210*y*	*y*
13	Ginter, *Angelina*	1937	60	0	8,922	5,579	0	0
14	Grapeland,[1] *Houston*	1936	1,*yyy*	0	25,277	23,945	*y*	*y*
15	Groesbeck, *Limestone*	1924	0	60			*y*	*y*
16	Hemby,[1] *Anderson*	1938	100*y*	0	350*y*	350*y*	102	102
17	Huntington, *Angelina*	1935	100	0	7,573	2,628	0	0
18	Joaquin,[1] *Shelby*	1936	6*yy*	6*yy*	2,445*y*	1,254	119	27
19	Lone Star, *Cherokee*	1938	100	0	6,239	6,239	*y*	*y*
20	Long Lake, *Anderson, Freestone*	1933	10,000	0	1,738,695	669,551	25,979	5,709
21	Lott, *Falls*	1937	300*y*	0	14,300	8,409	0	0
22	Mexia, *Limestone*	1920	3,920	0	96,059,812	667,631	*x*	*x*
23	Mount Calm, *Hill*	1929	10	0	*y*	*y*	0	0
24	Nacogdoches, *Nacogdoches*	1865	*y*	*y*	424,516*y*	1,314	0	0
25	Navarro Crossing, *Houston*	1938	500	2,000	25,644	25,644	100	100
26	Nigger Creek, *Limestone*	1926	170	0	2,998,965	155	0	0
27	Opelika,[5] *Henderson*	1937	1,*yyy*	0	24,547	22,042	448	422
28	Panola[6] (Bethany), *Panola*	1921	60	23,000	91,118	9,508	145,000	2,500
29	Percilla, *Houston*	1937	1*yy*	0	19,035	7,183	*y*	*y*
30	Post Oak, *Falls*	1924	20*y*	0	190,205	730	0	0
31	Potter (Caddo), *Marion*	1905	980	0	7,626,395	35,746	*y*	*y*
32	Pottsboro, *Grayson*	1928	20*y*	0	7,171*y*	1,551	350	(No gas produced since 1934)
33	Powell,[7] *Navarro*	1923	2,600	0	108,508,391	733,051	*x*	*x*
34	Red Lake, *Freestone*	1934	0	2,550			1,340	300
35	Richland, *Navarro*	1924	440	0	6,625,915	6,562	*x*	*x*
36	Rodessa (Dees-Young), *Cass*	1935	5,011	3,250	18,530,266	5,867,634	42,566	20,537
37	Rodessa (Gloyd), *Marion*	1937	4,036	10,150	3,172,768	3,172,768	5,711	5,711
38	Rodessa (Gloyd), *Cass*	1936	1,884	10,152	5,376,835	2,311,183	12,801	9,245
39	Rodessa,[8] Total		10,931	23,552	27,079,869	11,351,585	61,078	35,493
40	Rusk, *Cherokee*	1934	200	0	242,537	18,524	0	0
41	Satin, *Falls*	1932	10	0	1,630	70	0	0
42	Shelbyville, *Shelby*	1934	50	0	10,423	598	0	0

[a] Footnotes to column heads and explanation of symbols are given on page 240.

[1] "Distillate" wells.

[2] Oil produced from well drilled and abandoned in 1937 an appreciable distance from discovery well drilled in 1938.

[3] This includes Mildred, Angus-Edens, Hodge, Burk, Rice, Oil Ridge and Old Powell Shallow.

[4] Currie field figures include N. Currie.

[5] To end of 1938, 5582 bbl. of 38.9° gravity oil was produced from discovery well. Balance of production was from gas distillate well.

[6] Nacatoch 1100, gas; Buckrange 1700, oil; Barlow 2300, gas; Adams 2650, gas; Tiller (Paluxy) 2300, gas; Werner 3600, gas; Jeter (Glen Rose) 5700, gas; Pettit gas.

[7] This includes shallow production discovered and produced since 1923 in the Powell Woodbine producing area.

[8] Rodessa (Dees-Young), Cass County, gas estimated from 1800 cu. ft. gas per barrel of oil for years 1936 and 1937; 3500 cu. ft. gas per barrel of oil for year 1938. (Gloyd), Marion County, gas estimated from 1800 cu. ft. gas per barrel of oil since discovery. (Gloyd), Cass County, gas estimated from 1200 cu. ft. gas per barrel for year 1936 and 1937, 4000 cu. ft. gas per barrel of oil for year 1938.

Approximately 8 miles west of the East Texas field, in eastern Smith County, H. L. Hunt, Inc., No. 1 S. H. Bradley, T. Payne survey, was completed in the Glen Rose at a total depth of 7528 ft., for an initial production of 72.6 bbl. of 62.8° gravity distillate and 850 M cu. ft. of gas per day through ¼-in. choke. Gas from this well is used for gas-lift purposes in the East Texas field.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells					Oil-production Methods at End of 1938			Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1938
	Completed to End of 1938	During 1938		At End of 1938		Number of Wells			Initial	Average at End of		Gravity A.P.I. at 60° F.
		Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Flowing	Pumping	Miscellaneous		1937	1938	Weighted Average
1	7	1	0	3	3	3	2	0	y	y	y	40.2
2	33	0	1	20	0	0	20	y[20]	650	y	y	38.5
3	37y	0	y	37	0	0	37	0	y	y	y	41.0
4	5	1	0	1	4	1	0	0	y	y	y	24.7
5	4	0	0	4	0	4	0	0	2,660	y	y	64.7
6	283	63	0	250	33	283	0	2[21]	e1,750	e1,580	e1,535	28.6
7	1	1	0	1	0	1	0	0	2,900	0	y	62.8
8	2	1	0	2	0	0	2	0	390	y	y	29.3
9	2,937y	0	y	646	0	0	646	0	y	y	y	27.5
10	54y	0	0	13	0	0	13	0	y	y	y	40.5
11	26,083	1,703	208	25,588	14	19,164	5,746	678[20]	e1,620	e1,119	e1,109	39.0
12	14	13	0	13	1	7	7	0	1,394	y	y	37.0
13	4	1	0	2	0	0	2	0	y	y	y	20.9
14	4	0	0	1	3	4	0	0	y	y	y	{63.8; 43.5}
15	5	0	0	0	5			Gas only	875	y	y	Gas only
16	1	1	0	1	0	1	0	0	2,200	0	y	59.2
17	11	0	0	7	0	0	7	0	y	y	y	23.6
18	5	1	1	1	3	4	0	0	2,550	0	y	{37.0; 48.0}
19	2	3	0	3	0	1	0	0	1,375	0	y	35.0
20	109	34	0	109	0	107	0	3[20,21]	2,440	2,295	2,300	41.0
21	3	1	y	3	0	0	3	0	y	y	y	29.3
22	552	0	0	242	0	0	242	0	y	y	y	35.0
23	2	0	1	0	0	0	1	0	y	y	y	31.3
24	4y	0	y	37	0	0	37	0	y	y	y	23.0
25	7	7	0	4	1	7	0	0	2,640	0	y	34.6
26	75	0	0	1	0	0	1	0	y	0	0	40.0
27	2	0	0	2	0	1	0	1	{1,250y; 3,250}	y	y	{38.9; 58.7}
28	262y	2	y	137	121	254	4	0	y	y	y	28.0
29	1	0	0	1	0	1	0	0	y	y	y	41.0
30	y	y	y	1	0	0	1	0	y	y	y	33.0
31	60y	y	y	24	0	0	24	0	y	y	y	40.0
32	14	1	0	2	0	0	2	0	300	y	y	38.8
33	741y	0	y	169	0	0	169	0	800y	y	y	37.8
34	3	0	0	0	3			Gas only	1,855	y	y	Gas only
35	107	0	0	2	0	0	2	0	y	y	y	38.4
36	278	y	9	264	5	199	25	45	e2,700	e1,701	e1,127	42.1
37	134	y	0	125	9	121	9	4	e2,700	e2,677	e2,309	42.0
38	72	y	0	72	0	70	2	3	e2,700	e2,107	e1,371	42.0
39	484	114	9	461	14	390	36	52				
40	5	0	0	2	0	0	2	0	y	y	y	42.0
41	2	0	0	1	0	0	1	0	x	0	0	34.2
42	2	0	1	1	0	0	1	0	y	y	y	37.0

[20] Gas lift.
[21] Gas injection into reservoir.

In Gregg County, ½ mile south of Willow Springs (Greggton) and approximately ½ mile east of the producing limits of the East Texas field in the M. Mann survey, the Humble Oil and Refining Co. and the Gulf Oil Corporation completed their No. 1 E. Robertson as the discovery well for the Willow Springs field. This well was drilled to a total depth of 10,284 ft. in the Trinity. After being plugged back to 7910 ft.

TABLE 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1938	
	Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
1	Cisco	Pen	1,682	1,630	S, L	y	25	AF	Ellenberger	2,530
2	Woodbine	CreU	3,666	3,632	S	25	34	DS	Fredericksburg	4,648
3	Basal Walnut	CreL	475	450	DL	22	3	AF	Trinity	1,800y
4	Woodbine	CreU	5,695	5,285	S	11	30	D	Washita CreL	6,140
5	Glen Rose	CreL	5,940	5,934	L	23	15	D	Travis Peak	6,019
6	Woodbine	CreU	3,758	3,680	S	25	78	AF	Trinity	9,085
7	Glen Rose	CreL	7,528	7,435	S	y	10	A	Glen Rose	7,528
8	Strawn	Pen	4,219	3,848	S	y	20	ML	Strawn	4,219
9	Nacatoch-Navarro	CreU	1,260	800	Ss	y	12–20	AF	Woodbine	3,570
10	Woodbine	CreU	2,990	2,930	Sh	22	20	F	Woodbine	3,646
11	Woodbine	CreU	3,665	3,632	S	25	35	Shore-Line	Paluxy	5,020
12	Woodbine	CreU	3,105	3,085	S	20	10	AF	Travis Peak	6,518
13	Carrizo	Eoc	2,200	2,186	S	y	10	ML	Wilcox	2,265
14	Woodbine	CreU	6,025	5,975	S	25	40	A	Woodbine	6,033
15	Woodbine	CreU	2,960	2,945	Sh	20	15	F	Woodbine	3,208
16	Woodbine	CreU	5,487	5,458	S	y	29		Woodbine	5,487
17	Queen City	Eoc	1,483	1,458	S	y	8	ML	Mt. Selman	1,490
18	Upper Glen Rose Lower Glen Rose	CreL	4,107 5,138	4,097 5,070	L	y	10 30	D	Glen Rose	5,138
19	Woodbine	CreU	4,010	4,006	S	y	5	F	Woodbine	4,015
20	Woodbine	CreU	5,250	5,170	S	25	32	A	Trinity	9,966
21	Buda-Upper Washita	CreL	1,250	1,275	DL	y	10	F	Edwards	1,500
22	Woodbine	CreU	3,085	3,000	Sh	25	50	F	CreL or Older	8,847
23	Austin chalk	CreU	700	607	C	y	8	F	Travis Peak	3,398
24	Weches	Eoc	100	80	Sh	y	y	ML	CreL	5,484
25	Woodbine	CreU	5,895	5,874	S	21–24	Gas, 35 Oil, 9	D	Woodbine	5,895
26	Woodbine	CreU	2,870	2,820	Ss	25	15	F	Woodbine	3,509
27	Trinity Glen Rose	CreL	8,028	7,195	Ls	y	y	A	Travis Peak	9,320
28	Various[6]	CreU, L	5,700	1,100	S, L	y	40	A	Salt	11,303
29	Woodbine	CreU	5,670	5,665	S	y	5	A	Del Rio, CreL	6,634
30	Buda	CreL	1,046	1,025	L	y	10	F	Trinity	3,567
31	Nacatoch-Tokio	CreU	1,040 2,366	1,025 2,300	S	20	15	A	Tokio, CreU	2,366
32	Trinity (Basal)	CreL	838	830	S	y	8	MU	Ordovician or Older	6,004
33	Woodbine	CreU	3,000	2,925	Sh	25	40	F	Trinity	6,506
34	Woodbine	CreU	4,950	4,850	S	y	25	A	Woodbine	5,002
35	Woodbine	CreU	3,040	2,975	Sh	25	20	F	Glen Rose	5,414
36	Dees-Young, Lower Glen Rose	CreL	5,834	5,794	L	17	25	F		
37	Gloyd, L. Glen Rose	CreL	6,094	6,044	L, S	20	30	F		
38	Gloyd, L. Glen Rose	CreL	6,000	5,914	S	16	20	F		
39									Salt-CreL or Older	11,484
40	Woodbine	CreU	5,125	5,120	S	20	10	MU	Woodbine	5,302
41	Buda	CreL	1,160	1,000	L	20	20	AF	Glen Rose	1,409
42	Blossom	CreL	2,700	2,690	S, L	y	10	ML	Georgetown	3,400

it was gun-perforated at 7244–7286 ft. and completed in the Glen Rose for an initial production of 170 bbl. of 56.4° gravity distillate with 17,000 M cu. ft. of gas per day. The same operators completed their No. 1 Porter Horton in the Glen Rose at 7252–7278 ft. as a distillate well for an initial production of 360 bbl. of 57.5° gravity distillate and 36,000 M cu. ft. of gas per day. No. 1 Porter Horton is in the H. G. Hudson survey, ½ mile south of the discovery well, and approximately the same distance east of the East Texas field. These wells furnish gas for gas-lift purposes in the East Texas field.

In Anderson County, H. L. Parson's No. 1 H. B. Hemby, in the J. Gossett survey, was drilled to a total depth of 5487 ft. and completed as a gas well with an initial production of 21.5 bbl. of 59.2° gravity distillate

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Year of Discovery	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[a]	To End of 1938	During 1938	To End of 1938	During 1938
43	Sulphur Bluff, *Hopkins*	1936	728	0	3,400,912	1,645,707	0	0
44	Talco, *Titus, Franklin*	1936	8,343	0	20,702,872	9,476,491	0	0
45	Trinity (Kittrel), *Houston*	1934	280	0	1,309,860	211,659	*y*	*y*
46	Van, *Van Zandt*	1929	4,521	0	116,084,363	5,562,017	*y*	*y*
47	Van (Shallow), *Van Zandt*	1933	200	0	235,046	32,566	*y*	*y*
48	Van, Total		4,721	0	116,319,409	5,594,583	*y*	*y*
49	Waskom, *Harrison*	1924	1,500	6,000	35,717	19,746	92,685	2,132
50	Willow Springs,[1] *Gregg*	1938	*x*	*x*	2,305	2,305	23.5	23.5
51	Wortham,[9] *Freestone*	1924	715	0	22,526,556	31,275	*x*	*x*
52	Total[10]				1,752,421,282*y*	182,369,484*y*	363,772.5*y*	54,327.5*y*
	ABANDONED FIELDS	LIFE						
53	Beulah (Lee-Tex),[11] *Angelina*	5 mo.	10	0	750	0	0	0
54	Camp Hill,[12] *Anderson*	3 yr.	200	0	286,414	0	0	0
55	Cedar Creek,[13] *Limestone*	4 yr.	30	0	297,945	0	0	0
56	Chatfield,[14] *Navarro*	5 yr.	0	150			4,750	0
57	Deberry,[15] *Panola*	2 yr.	100	50	29,166	0	0	0
58	Kosse,[16] *Limestone*	8 days	10	0	33,000	0	0	0
59	Tacoma, *Panola*[17]	5 yr.	40	0	15,750	0	0	0
60	Witherspoon-McKie,[18] *Navarro*	20 yr.	400	0	810,495	0	0	0
61	Total				1,444,354			
62	Grand Total				1,753,894,802*y*	182,369,484*y*	368,522.5*y*	54,327.5*y*

[9] Wortham shallow discovered in 1912 included with Wortham.

[10] Production for year 1937 has been corrected from Texas Railroad Commission records. Production for year 1938 also from Texas Railroad Commission records. For all fields discovered since 1935 the cumulative production has been corrected from Texas Railroad Commission records.
For 1938, 45,847 bbl. of distillate has been included in total production figure.

[11] Discovered in 1935, abandoned in 1935.

[12] Discovered in 1934, abandoned in 1937.

[13] Discovered in 1927, abandoned in 1931.

[14] Discovered in 1905, abandoned in 1910.

[15] Discovered in 1931, abandoned in 1932.

[16] Discovered in 1922, abandoned in 1922.

[17] Discovered in 1933, abandoned in 1938.

[18] Discovered in 1915, abandoned in 1935.

and 8150 M cu. ft. of gas per day on ½-in. choke, with a gas-oil ratio of 379,069 to 1. Flowing pressures were: casing 2050 lb., tubing, 1400 lb., shut-in pressures, casing and tubing, 2200 pounds.

The only activity in the Opelika field, Henderson County, during the year was the starting on Oct. 30, 1938, of Tidewater-Seaboard-Humble's No. 1 Sallie Starr McGee well in the R. Acosta survey. This well, which extended the limits of the field one mile north, was completed on Jan. 29, 1939, for an initial production of 436 bbl. of water-white distillate on ½-in. choke with a gas-oil ratio of 18,000 to 1. Flowing pressures were: tubing 1625 lb.; casing, 1900 lb. Shut-in pressures were: tubing, 3100 lb.; casing, 3230 lb. The well was drilled to a total depth of 8216 ft. and was gun-perforated from 8170 to 8180 ft., with 47 shots in the Glen Rose.

Deep Wells

Two deep wells have been drilled in this district, which have penetrated salt, underlying formations of Lower Cretaceous age. It is not known whether this salt is Lower Cretaceous or older. The Stanolind

Table 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells					Oil-production Methods at End of 1938			Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1938
	Completed to End of 1938	During 1938		At End of 1938		Number of Wells			Initial	Average at End of		Gravity A.P.I. at 60° F.
		Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Flowing	Pumping	Miscellaneous		1937	1938	Weighted Average
43	74	1	y	74y	y	14	60	0	e1,900	e1,850	e1,650	22.4
44	686	87	y	686	0	0	686	0	e1,900	y	1,150[22] 1,650[23]	20.6
45	15	2	1	15	0	0	15	0	870	y	y	24.0
46	571	2	3	559[19]	0	341	218	0	e1,230	e1,137	e1,127	34.0
47	31	1	0	31	0	0	31	0	y	y	y	31.0
48	602	3	3	590	0	341	249					
49	225y	y	y	19y	79	y	19	0	y	y	y	28.0
50	2	2	0	2	0	2	0	0	2,870	y	y	56.9
51	322	0	y	10	0	0	10	0	y	y	y	29.0 37.0
52	33,853y	2,043y	225y	29,147y	324	20,590y	8,006	733				
53	1	0	0	0	0	0	0	0	200y	0	0	24.0
54	10y	0	0	0	0	0	0	0	1,950	y	y	40.6
55	14	0	0	0	0	0	0	0	y	y	y	37.0
56	15	0	0	0	0	0	0	0	250	0	0	Gas only
57	22	0	0	0	0	0	0	0	757	0	0	46
58	1	0	0	0	0	0	0	0	x	0	0	32.0
59	3	0	0	0	0	0	0	0	y	0	0	46.0
60	85	0	0	0	0	0	0	0	x	0	0	19.0
61												
62	33,982y	2,043y	225y	29,147y	324	20,590y	8,006	733				

[19] Three wells producing from sub-Clarksville sand.
[22] Carr sand.
[23] Gault sand.

Oil and Gas Co. drilled its No. 1 T. Norris, in the K. Thrasher survey, to a total depth of 9951 ft. and topped salt at 8995 ft. This test was approximately 5 miles north of Kosse, in Limestone County. In the Bethany area, Panola County, the Texas Company drilled its No. 1-C, T. C. Adams to a total depth of 11,303 ft. and topped salt at 11,067 feet.

Classification of "Distillate" or "Condensate" Wells

The status of "distillate" wells, according to the rules and regulations of the Texas Railroad Commission, has become of appreciable importance to the East Texas district as well as other districts in the state. On Jan. 18, 1939, the Commission issued an order classifying wells producing "condensate" in the state of Texas. Apparently the only solution for economic recovery of "distillate" is pressure maintenance of the reservoir fluids and the recycling of gas by means of input wells to reservoirs in order to properly maintain reservoir pressures.

Recycling Operations

Recycling projects now in operation and under construction in this district are listed in Table 4.

Table 1.—(*Continued*)

Line Number	Producing Formation								Deepest Zone Tested to End of 1938	
	Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft
43	Paluxy	CreL	4,523	4,487	S	25	36	AF	Glen Rose	6,600
44	Paluxy	CreL	4,300	4,200	S	20	35	AF	Glen Rose	5,903
45	Carrizo	Eoc	2,013	1,995	S	y	10–60	Ds	Salt {Dome Material}	3,855
46	Woodbine	CreU	2,950	2,682	S	y	268	AF	Travis Peak	7,501
47	Nacatoch	CreU	1,220	1,200	S	y	20	AF	Travis Peak	7,501
48										
49	{Nacatoch, Blossom, Glen Rose}	CreU, L	4,650	800	S, Sh, L	y	15–40	A	Glen Rose	4,980
50	Glen Rose	CreL	7,286	7,244	S, L	y	35		Lower Marine	10,284
51	Nacatoch Woodbine	CreU	1,371 3,050	1,361 2,990	S	25	6 35	F	Glen Rose	4,825
52										
53	Queen City	Eoc	2,053	2,045	S	x	5	Shallow	Carrizo	2,324
54	Sub-Clarksville (Eagle Ford); Woodbine	CreL	5,059	5,054	S, Sh	y	5	AF	Lower Glen Rose	8,383
55	Woodbine	CreU	2,940	2,885	Sh	25	10	F	Woodbine	3,310
56	Taylor sand	CreU	1,020	880	Ss	x	13	A	Woodbine	3,057
57	Blossom	CreU	2,087	1,990	Sh	y	y	ML	Blossom	2,125
58	Unknown	x	3,767	x	x	x	x	Crev.	Glen Rose	6,056
59	Blossom	CreU	2,085	2,073	S	y	10	Shallow	Blossom	2,302
60	Nacatoch	CreU	875	825	Ss	14	19	AF	Woodbine	3,480
61										
62										

Salt-water Disposal

The question of salt-water disposal has assumed a role of increasing importance in the East Texas, Talco, and Sulphur Bluff fields. In the East Texas field, four experimental projects for salt-water disposal are now operating, and 12 more are reported to be under consideration. Chemical treatment of the salt water is required before it is returned to the lower portion of the Woodbine sand section by means of disposal wells.

The Humble Oil and Refining Co. drilled its No. 37 W. W. Holland in the T. Allen survey in Gregg County to the Paluxy sand at 5020 ft. and made tests to determine whether or not the sand was suitable for the disposal of salt water. This test was not successful because of sand characteristics encountered in this well. After testing, the well was plugged back to the Woodbine and completed as an oil well. This is the deepest well drilled to date in the East Texas field within the confines of the Woodbine sand producing area.

In the Talco field for the past 18 months salt water has been returned to the Nacatoch sand, which is found at a depth of approximately 900 ft. in the south part of the field. Settling pits are used for treating the salt water before it is disposed of. One disposal well, in the south portion of the field, is operating with an average input pressure of approximately 165 lb. per sq. in.; about 5500 bbl. of salt water are returned per day. This disposal well has approximately 100 ft. of sand exposed.

Operators in the Sulphur Bluff field have two proposed salt-water disposal projects at this time. One injection well has been tested for

Table 2.—*Summary of Drilling Operations in East and East Central Texas*

Important Wildcats Drilled in 1938

	County	Location: Survey	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
1	Anderson	J. Gossett	5,487	Claiborne	Woodbine
2	Cherokee	W. Walters	4,008	Claiborne	Woodbine
3	Falls	P. Zarzo	1,015	Taylor	Georgetown
4	Franklin & Titus	Geo. Dyer	4,367	Midway	Paluxy
5	Grayson	Chas. Quillan	4,043	Woodbine	Strawn
6	Gregg	M. Mann	10,284	Wilcox	Glen Rose
7	Harrison	T. D. Wilson	5,025	Wilcox	Glen Rose
8	Houston	J. L. Riviere	5,921	Claiborne	Woodbine
9	Leon	Jas. Webb	5,633	Claiborne	Woodbine
10	Limestone	K. Thrasher	9,951	Midway-Wilcox	Lower Cretaceous? Salt
11	Panola	Thos. Cox	11,303	Wilcox	P.B. to Glen Rose
12	Sabine	I. Low	5,886	Midway	?
13	Shelby	W. M. Snider	5,138	Wilcox	Glen Rose
14	Smith	T. Payne	7,528	Claiborne	Glen Rose

the return of salt water to the Nacatoch sand, but the test was not altogether successful. Since that time salt water has been run to pits and evaporated.

Prices

The trend of crude-oil prices during the year was downward. The following important changes in posted prices were made in this district:

East Texas Field.—On Aug. 20, 1938, the East Texas Refining Co. reduced the price of East Texas crude from $1.35 to $1.20 per barrel. The American Liberty Pipe Line Co. posted a price of $1.25 per barrel, effective Aug. 29, 1938. On Oct. 11, 1938, the Humble Pipe Line Co. further reduced the price to $1.10 per barrel.

Talco Field.—At the beginning of the year the Humble Pipe Line Company's posted price was $0.73 per barrel. On Oct. 11, 1938, the Humble Pipe Line Co. reduced the posted price to $0.55 per barrel.

Rodessa Field (*Texas*).—During January 1937, the posted price for crude oil was $1.25 (flat) per barrel for 40° gravity crude and above. On

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	H. L. Parsons	21.5	8.15	½	2,050	1,400	Hemby field, 59.2° gravity
2	J. R. Bunn et al	86.0	1.0	⅜	1,280	1,375	Lone Star field, 35° gravity oil
3	J. Lee Davis	6.0		Pump			Satin field,[2] 34.2° gravity oil
4	Magnolia Petroleum Co.	210.0		Pump			East extension to field, ½ mile
5	Mildred Oil Co.	269.0		Pump			Collinsville field 29.3° gravity oil
6	Humble-Gulf Cos.	170.0[1]	17.0	2-in. tubing		2,610	Willow Springs field, P. B. 7910 ft., 56.4° gravity
7	Ark.-La. Gas Co.		18.0	2		2,010	P.B. to 4834 ft.
8	Humble Oil & Rfg. Co.	296.0	1.3	¼	2,200	1,980	Navarro Crossing field, 34.6° gravity oil
9	J. K. Hughes et al.	152.0	0.45	¼	1,950	1,025	Buffalo field, 24.7° gravity oil
10	Stanolind Oil & Gas Co.	D. & A.					5 miles north of Kosse. Drilled through salt
11	Texas Co. (Allen et al.)	358.0[1]	17.9	2½-in. tubing	S.I.P. 2,300	S.I.P. 2,300	Bethany field, P.B. to 5735 ft.
12	H. R. Smith, Inc.			Gas blowout			Not completed. T.A.
13	W. M. Redditt el al. (Pundt and Johnson)	10.0	10.0	11/64	1,900	1,850	Joaquin field,[2] 48° gravity oil
14	H. L. Hunt, Inc.	72.6[1]	0.850	¼	3,125	2,900	Chapel Hill field, 62.8° gravity

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1938	63	28
Number of oil wells completed during 1938	2,034	5
Number of gas wells completed during 1938	36	4
Number of dry holes completed during 1938	60	103

[1] Distillate wells.
[2] New oil wells in old fields.

Oct. 12, 1938, the Magnolia Pipe Line Co. reduced the posted price to $1.05 per barrel for 40° gravity crude and above.

TABLE 3.—*Production Statistics, East Texas Field*

Date	Average Reservoir Pressures at −3300 Ft., Lb. per Sq. In.	Production, Bbl. (42 U.S. Gal.)	Number of Days Shut Down
Jan. 7	1119.98	14,122,624	2
Feb. 8	1127.06	11,829,671	4
Mar. 8	1123.24	13,400,409	4
Apr. 8	1118.26	12,963,723	4
May 8	1116.15	11,543,936	8
June 8	1120.84	11,093,135	8
July 8	1125.45	13,196,466	5
Aug. 8	1121.64	13,753,755	4
Sept. 8	1111.30	11,244,182	8
Oct. 8	1106.70	11,802,597	8
Nov. 8	1108.21	11,347,377	8
Dec. 8	1109.71	11,892,038	8
Average	1117.38	Total 148,189,913	Total 71

TABLE 4.—*Recycling Projects*

Operator	County	Field	Reported[1] Plant Hp.	Approx. Capacity, M Cu. Ft. Gas per Day	Input[2] Well Pressures, Lb. per Sq. In.
Portex Oil Co.	Shelby	Joaquin	1—600[3]	20,000	2,300
Tide Water-Seaboard	Anderson & Henderson	Cayuga	1—400 2—300	25,000	1,650
Tide Water-Seaboard	Anderson & Freestone	Long Lake	1—400 2—300	25,000	2,150
Trinity Gas Co.	Anderson & Freestone	Long Lake	1—600	18,000	2,150
Anco Gas Co. (Byrd-Frost, Inc.).	Anderson & Freestone	Long Lake	1—500 2—150 1—100	16,000	2,080
American Liberty Oil Co.	Houston	Grapeland	1—500	18,000	2,250

[1] The horsepower required per million cubic feet of plant capacity will vary with operating conditions, as influenced by plant design.

[2] Represents best available estimates or reported operating-well input pressures.

[3] Number of units.

Cayuga Field.—On Oct. 19, 1938, the posted price of Tide Water Associated Oil Co. was $0.81 per barrel. On Feb. 16, 1939, this company withdrew from the field as a purchaser. The Pan-American Petroleum

and Transport Co., effective 7:00 a.m., Feb. 16, 1939, took over the field runs and posted a price of $0.68 per barrel.

Sulphur Bluff Field.—At the beginning of the year 1938, the American Liberty Pipe Line Company's posted price was $0.73 per barrel. On Oct. 11 of this year, the price was reduced to $0.55 per barrel.

Pipe-line Construction

The Humble Pipe Line Co. completed a combination 4-in. and 6-in. oil pipe line from its Mildred station in Navarro County to the Flag Lake field in Henderson County, a distance of 20 miles, giving this field a pipe-line outlet. Heretofore the only oil outlet for this field has been by tank truck. A gas pipe line was laid by H. L. Hunt, Inc., from Chapel Hill to the East Texas field for gas-lift purposes. This line is 25½ miles long —8 miles of 6⅝-in. line; 15 miles of 5-in. line; and 2½ miles of 4½-in. line.

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Oil and Gas Production on the Texas Gulf Coast during 1938

By E. P. Hayes,* Member A.I.M.E., and E. D. Cockrell*

(New York Meeting, February, 1939)

The figures herein presented show that during the year 1938 drilling in the Texas Gulf Coast continued at a slightly lower rate than during 1937. In 1938 there were 21 new oil fields added to the Texas Gulf Coast; also numerous extensions and new sands in old fields. This report for 1938 cannot be compared with the report for 1937 in Volume 127 of the Transactions, because the area covered by this report is less than that covered last year. The cross-hatched area on Fig. 1 shows the limits of this report.

Of the new fields, Cordele, in Jackson County, Eureka Heights and Fairbanks, in Harris County, Francitas, in Jackson County, LaRosa, in Refugio County, and League City, in Galveston County, have the greatest promise of prolific production.

The 1938 production for the Gulf Coast area was 92,530,467 bbl. as compared to 94,019,355 bbl. for the same area in 1937. This shows a decrease of 1,488,888 bbl. during 1938, regardless of the increase due to the 21 new oil fields. This decrease was caused mainly by the Saturday and Sunday shutdowns (68 days during 1938) and by cut in allowables. The 68 shut-down days amount to approximately 18.6 per cent of the 365 days possible for production. The decrease in the 1938 production amounted to approximately 1.58 per cent. Therefore there was actually a potential increase in the year's production.

During the past year, 1637 wells were completed as oil wells, 68 as gas wells and approximately 461 dry holes, as compared to 1672 oil wells, 83 gas wells and 448 dry holes in 1937 on the Texas Gulf Coast. Total wells drilled were 2166 in 1938 and 2203 in 1937.

Condensate sands in old fields and new fields are continuing to increase in importance from the standpoint of retrograde condensation and pressure maintenance.

The following fields had major extensions during the year 1938 from the standpoint of increased areas of old sands and new deeper sands:

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* Producing Department, The Texas Company, Houston, Texas.

Field	County	Field	County
Clinton	Harris	Hastings	Brazoria
Webster	Harris	Withers	Wharton
Keeran	Victoria	Cleveland	Liberty
McFaddin	Victoria	Hardin	Liberty
Heyser	Victoria	La Blanca	Hidalgo
Placedo	Victoria	West Orange	Orange
Refugio	Refugio	Segno	Polk
West Columbia (New)	Brazoria		

New Fields

Armour Field, Matagorda County.—The Armour field was discovered by the Pierce Estates on their fee lands. The well was completed at 6620 to 6624 ft. for 241 bbl. of oil and 96,000 cu. ft. of gas on a $\frac{3}{16}$-in. positive choke. The production is from a Frio sand.

Bammel Field, Harris County.—The Bammel field has two producing sands, 6170 to 6175 ft. and 6205 to 6211 ft. The production is from the Cockfield. The deepest zone tested was the Wilcox at 10,574 feet.

Cedar Point Field, Chambers County.—This field was discovered by the Standard Oil Company of Texas and the Salt Dome Oil Company's State No. 1 in Galveston Bay. The well was completed in the Frio at 5967 ft. for 650 bbl. of oil on a $\frac{1}{4}$-in. positive choke. A new sand was later discovered at 4430 ft. for an extension. The deepest zone tested was the Frio at 6528 feet.

Chreisman Field (Red Bank), Burleson County.—The Chreisman field is important in that the production is from the Edwards lime at 6167 to 6172 ft. The discovery well was the Red Bank Oil Company's Coffield No. 1, completed for 127 bbl. of oil per day by pumping.

Clear Lake Field, Harris County.—The West Production Company's Sowden No. 1 well discovered this field at 5805 ft. in the upper Frio. It was completed as a well with 5 bbl. condensate and considerable gas with 2390 lb. pressure on both the tubing and casing.

Cordele Field, Jackson County.—The Cordele field has enjoyed considerable development since its discovery by Potter and Adam's Faust No. 1, completed at 2675 ft. in the Catahoula for 270 bbl. of oil per day on a $\frac{3}{16}$-in. positive choke. The Vicksburg has been tested at 5177 feet.

Eureka Heights Field, Harris County.—Jack Frazier's No. 1 Vollmer-Neiman discovered the Eureka Heights field in the upper Saline Bayou at 7722 ft. for 616 bbl. of oil with 462,000 cu. ft. of gas on a $\frac{1}{4}$-in. choke, tubing pressure 1100 lb. and casing pressure 1510 lb. per sq. in. Jack Frazier also discovered a new sand at 8096 ft. with his L. Lackner No. 1.

Fairbanks Field, Harris County.—Amerada-Stanolind's Mills No. 1 discovered Fairbanks in the Cockfield at 6853 ft. Union Producing Co.

found a new sand at 7185 ft. in its Goodykoontz No. 1. This field is one of the more important fields of 1938.

Francitas Field, Jackson County.—The Francitas field was discovered by The Texas Company's Weed No. 1 at 7468 ft., which was completed as a distillate producer from a very prolific sand. Wynn Crosby's Broughton No. 1 completed in an oil sand at 7417 feet.

Fig. 1.—Area of Texas Gulf Coast covered in this report.

La Rosa Field, Refugio County.—This field began as a Frio producer discovered by Coronada Exploration Company's Rooke No. 2 at 5370 ft. for 25 bbl. of oil on a ¼-in. choke. Subsequent wells have discovered several new sands, one at 5920 ft. and another at 6328 feet.

League City Field, Galveston County.—Midwest Royalty Co. completed its Lobit No. 1 in the League City field at 9106 ft. in the Frio, for

TABLE 1.—*Oil and Gas Production on Texas Gulf Coast in 1938*

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[a]	To End of 1938	During 1938	To End of 1938	During 1938
1	Allen, *Brazoria*	12	10	0	87,598	2,673	63[1]	*x*
2	Amelia, *Jefferson*	3	1,230	0	2,667,017	1,290,348	1,509[1]	645[1]
3	Anahuac, *Chambers*	4	6,745	0	10,128,206	2,883,779	7,140[1]	1,450[1]
4	Aransas, *Aransas and San Patricio*	3	3,700	20	2,853,625	1,911,765	6,848[1]	4,588[1]
5	Armour, *Matagorda*	1	80	0	42,489	42,489	26[1]	26[1]
6	Arriola, *Hardin*	7	100	0	1,846,576	164,888	650[1]	32[1]
7	Bammel, *Harris*	1	100	0	12,850	12,850	9[1]	9
	Barbers Hill, *Chambers:*							
8	2,300 ft.	23	70	0	1,735,214	0	*x*	*x*
9	5,200 ft.	11	445	0	61,714,151	3,407,964	*x*	*x*
	Batson, *Hardin:*							
10	350–2,600 ft.	36	600	*y*	738,847,562	281,646	*x*	*x*
11	4,890–5,600 ft.	5		*y*		315,356	*x*	*x*
12	Bay City (Van Vleck), *Matagorda*	5	1,200	0	1,848,752	759,527	925[1]	360[1]
13	Big Creek, *Ft. Bend*	17	200	0	9,591,005	227,245	*x*	*x*
14	Big Hill, *Jefferson*	16	10	0	13,853	Prod. depleted 1924	*x*	0
15	Big Hill, *Matagorda*	35	15	0	210,906	Prod. depleted 1907	*y*	0
16	Blue Ridge, *Ft. Bend*	20	325	0	10,829,546	247,800	*x*	*x*
17	Boling, *Ft. Bend and Wharton*	14	304	0	6,166,661	536,992	*x*	429[1]
18	Brenham, *Austin and Washington*	24	60	0	355,789	9,728	*x*	*x*
19	Brookshire, *Waller*	5	50	0	21,314	1,932	12	*x*
20	Buckeye, *Matagorda*	7	50	0	693,288	47,081	690[1]	36[1]
21	Burnell (South), *Karnes*	2	330	210	447,244	322,831	1,407[1]	646[1]
22	Caesar, *Bee*	5	285	185	823,687	88,130	2,200[1]	417[1]
23	Call, *Newton*	2	100	0	15,376	9,809	5[1]	3[1]
24	Cedar Point, *Chambers*	1	410	0	113,249	113,249	150	150
25	Cheek, *Jefferson*	2	100	0	60,316	39,279	34[1]	23[1]
26	Chreisman (Red Bank), *Burleson*	1	20	0	4,531	4,531	1[1]	1[1]
27	Clam Lake, *Jefferson*	2	100	0	34,596	33,361	35[1]	33[1]
28	Clay Creek, *Washington*	11	400	0	4,142,805	191,272	*x*	217
29	Clear Lake, *Harris*	1	600	0	37,429	37,429	26[1]	26[1]
30	Cleveland, *Liberty*	5	400	0	1,069,762	141,761	642[1]	85[1]
31	Clinton, *Harris*	3	140	0	94,190	90,291	1,081[1]	490[1]
32	Coletto Creek, *Victoria*	5	500	350	898,802	169,378	850[1]	169[1]
33	Conroe, *Montgomery*	7	20,000	0	98,259,432	11,385,364	65,045	2,850[1]
34	Cordele, *Jackson*	1	320	0	113,539	113,539	34[1]	34[1]
	Cotton Lake, *Chambers:*							
35	6,302 ft.	3	600	*y*	452,190	190,464	271[1]	114[1]
36	South, 6,503 ft.	2			469,295	336,558	281[1]	201[1]
37	Damon Mound, *Brazoria*	24	10	0	9,439,217	110,741	*x*	*x*
38	Danbury, *Brazoria*	9	200	20	129,027	114,760	187[1]	80[1]
39	Diamond Half, *Goliad*	3	240	0	284,060	94,633	103[1]	27[1]
40	Dickinson, *Galveston*	5	2,500	0	3,681,248	1,417,788	14,800[1]	5,600[1]
41	Dinero, *Live Oak*	4	50	20	64,476	9,640	*x*	*x*
42	Dirks, *Bee*	5	865	0	4,452,338	807,086	3,116[1]	465[1]
43	Edna, *Jackson*	18	0	105	0[2]	0[2]	*x*	*x*

[a] Footnotes to column heads and explanation of symbols are given on page 240.
[1] Estimated. [2] Distillate.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Producing Oil[b]	At End of 1938: Producing Gas[c]	Oil-production Methods at End of 1938, Number of Wells: Flowing	Pumping	Gas Lift	Pressure, Lb. per Sq. In.[d]: Initial[4]	Average at End of 1937[4]	Average at End of 1938[4]	Character of Oil, Approx. Average during 1938: Gravity A.P.I. at 60° F., Weighted Average
1	5	0	0	1	0	0	1	0	200	y	0	34.3
2	120	8	0	114	4	114	0	0	925	750	725	29.2
3	282	42	0	262	10	261	0	1	e3,260	1,250	1,025	34.4
4	148	49	0	40	2	139	0	1	2,200	1,600	400–1,670	42.
5	3	3	0	3	0	3	0	0	1,000y		1,000y	34
6	15	0	0	12	0	2	10	0	1,400	x	pump	34
7	1	1	0	1	0	1	0	0	2,450y		2,450y	55
8	417	0	0	0	0	0	0	0	x	x	x	x
9		16	8	163	0	31	121	11	296	x	300[5]–pump	26
10	1,012x	16x	0	203	0	0	203	0	x	x	pump	y
11			0	17	0	8	9	0	x	x		38.1
12	32	9	0	32	0	32	0	0	3,350–3,650	3,350–3,650	3,350–3,650	36–48
13	82	0	0	24	0	0	24	0	400	y	pump	28
14	6	0	1	0	0	0	0	0	x	x	x	x
15	3	0	0	0	0	0	0	0	x	x	x	x
16	187	2	4	58	1	5	53	0	385	x	pump	26
17	171	9	0	92	1	43	49	0	x	x	y	28.3
18	66	1	0	34	2	0	34	0	x	x	pump	17
19	1	0	0	1	0	0	1	0	100	0	pump	24
20	3	1	0	3	0	3	0	0	1,045	x		38
21	40	8	0	32	6	30	2	0	1,425	x	100–1,200	47
22	41	0	0	25	8	0	25	0	1,140[3] 315	x	pump	22
23	1	0	0	1	0	0	1	0	1,475	1,450	pump	39.6
24	9	9	0	9	0	9	0	0	e2,750		e2,750	36.9
25	4	2	0	4	0	4	0	0	2,950	2,050		43.9
26	1	1	0	1	0	0	1	0	1,675		1,675	34.5
27	3	2	0	3	0	2	1	0	e2,500	y	y	20 33.2 34.2
28	67	1	0	49	3	3	46	0	350	x	pump	24.7
29	3	2	0	2	1	2	0	0	650		650	28.7
30	23	1	0	13	3	13	0	0	2,400	1,800	y	40
31	12	7	0	8	2	6	2	0	4,800	x	y	48
32	28	0	0	20	4	18	2	0	x	x	550	25
33	971	8	1y	947	3	922	25	0	e2,275	x	pump to e2,275	38
34	14	14	0	14	11	14	0	0	80–340		80–340	22
35	9	4	0	9	0	9	0	0	1,050	950	925	30.2
36	28	13	0	25	1	25	0	0				
37	130	1	0	30	0	0	30	0	x	x	x	26
38	14	8	0	9	1	6	3	0	500	500	500	23
39	21y	0	0	21	0	1	20	0	x	x	pump	47
40	125y	54	0	106	10	104	0	2	1,250[4]	1,250[4]	1,158	37.5
41	4	0	0	2	0	11	1	0	1,600	y	pump	43
42	100	0	0	95	0	36	59	0	1,000	700	0–500	44
43	13	0	0	0	2y	y	0	0	x	x	y	y

[3] Gas. [4] Flowing pressure through tubing on small choke.
[5] Production used to develop field.

TABLE 1.—(*Continued*)

Line Number	Producing Rock								Deepest Zone Tested to End of 1938	
	Name	Age[e]	Depth, Average in Feet		Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
			Bottoms of Productive Wells	To Top of Productive Zone						
1	Mio	Mio	5,030		SH	Por	10	Ds	Mio	5,958
2	Frio	Olig	6,780	6,745	Ss	Por	15	D	Frio	8,261
3	Marginulina, Frio	Olig	7,085	7,000	Ss	Por	60	Df	Frio	8,749
4	Marginulina, Frio	Olig	7,313	6,544	Ss	25–34	20	Ny	Frio	8,889
5	Marginulina, Frio	Olig	6,624	6,620	Ss	Por	4	N	Frio	7,531
6	Mio, Frio	Mio, Olig	4,400	2,990	Ss	Por	50±	Ds	Yegua	6,743
7	Cockfield	Eoc	6,175–6,211	6,170–6,205	Ss	Por	10	Dsf	Wilcox	10,574
8	Pli, Mio	Pli, Mio	2,300	800	Ss	Por	42x	Ds		
9	Mio, Frio	Mio, Olig	6,690	3,450	Ss	30	80x	Ds	McElroy	8,148
10	Cap rock, Lissie, Lagarto	Pre-Ter	1,250		L	Cav	y	Ds		
11	Mid-Olig, Yegua	Pli, Mio, Olig, Eoc	5,500	5,470	Ss	Por	30	Ds Ds	Cook Mt.	6,502
12	Marginulina, Frio	Olig	7,075 7,495–8,250	7,000	SH	30	21 60 60	D	Vicksburg	11,467
13	Pli, Mio, Mid-Olig, Frio	Mio-Olig	3,850		SH	Por	54	Ds	Jackson	5,536
14	Pli, Mio	Pli, Mio	2,500		S	Por	10	Ds	Marginulina	6,742
15	Cap rock, Mio	Pre-Ter, Mio	862		Lx	Cav, Por	x	Ds	x	3,705
16	Mio, Mid-Olig, Frio	Mio-Olig	3,600	3,000	SH	30+	60	Ds	Jackson	6,189
17	Cap rock, Mid-Olig, Frio	Pre-Ter Olig	500 4,089 4,859	377 2,500 4,817	L, SH	Cav, Por	60	Ds	Frio	5,543
18	Oakville, Cockfield	Mio, Eoc	482–1,500	190–1,400	SH	Por	10x	Ds	Carrizo	3,930
19	Frio	Olig	2,974	2,955	Ss	Por	16	D	Hockleyensis	7,215
20	Frio	Olig	7,926	7,831	SH	Por	60	D	Frio	10,503
21	Cockfield (Pettus)	Eoc	3,674	3,617	Ss	Por	12	DF	Yegua	5,280
22	Cockfield (Pettus)	Eoc	3,039	3,021	Ss	Por	15	DF	Yegua	4,502
23	Cockfield	Eoc	6,918	6,908	Ss	Por	7	NF	Yegua	7,380
24	Frio	Olig	6,000	5,950	Ss	35	35	Ds	Frio	6,528
25	Frio, Vicksburg	Olig, Eoc	7,725–8,565	7,690	S	Por	10	MF	Vicksburg	8,841
26	Edwards	CreU	6,172	6,167	L	Cav	5	MF	Edwards	6,172
27	Mio	Mio	3,855 5,929 5,960	3,844 5,913 5,955	Ss	32.3 42.2 37.0	16 5 10	Ds	Frio	8,198
28	Claiborne, Wilcox	Eoc	1,250		SH	Por	120	Ds	Wilcox	8,306[6]
29	Frio	Olig	5,910	5,880	Ss	Por	15	D	Frio	7,582
30	Cockfield, Yegua	Eoc	5,900	5,700	Ss	15	8	MF	Cook Mt.	8,734
31	Mio, Cockfield	Mio, Eoc	3,829–8,101[2]	3,220 8,080	Ss	Por	20	D	Cockfield	8,783
32	Catahoula, Frio	Mio, Olig	2,226[3]–2,880	2,861	Ss	Por	10	MF	Frio	5,368
33	U. Cockfield, Conroe	Eoc	5,150	5,000	Ss	27x	14 56	D	L. Saline Bayou	8,011
34	Mio	Mio	2,753	2,654	Ss	Por	15	Df	Vicksburg	5,177
35	Marginulina	Olig	6,310	6,302	Ss	Por	5	Df	Frio	7,019
36	Marginulina	Olig	6,520	6,503	Ss	Por	8	Df		
37	Mio, Mid-Olig, Vicksburg	Mio, Olig	3,800	1,406	SH	Por	43x	Ds	Vicksburg	8,112[6]
38	Pli, Mio	Pli, Mio	1,970	1,955	Ss	Por	20	Ds	Frio	7,495
39	Cockfield (Pettus)	Eoc	3,880	3,684	Ss	Por	14	DF	y	y
40	Frio	Olig	8,050–9,121	7,980–9,080	Ss	Por	12	DF	Frio	9,463
41	Yegua	Eoc	5,220	5,200	S	Por	7	D	Cook Mt.	5,913
42	Cockfield (Pettus)	Eoc	3,990	3,819	Ss	Por	16	DF	Yegua	4,776
43	Frio	Olig	4,655	4,640	Ss	Por	15y	D	Cockfield	7,180

[6] In salt.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[a]	To End of 1938	During 1938	To End of 1938	During 1938
44	Esperson, *Liberty*	10	465	0	5,282,983	495,811	2,120[1]	50[1]
45	Eureka Heights, *Harris*	1	600	200	255,131	255,131	765[1]	765[1]
46	Fairbanks, *Harris*	1	2,500	0	814,172	814,172	407[1]	407[1]
47	Fannet, *Jefferson*	12	105	0	2,408,436	203,208	1,204[1]	20[1]
48	Fort Merrill, *Live Oak*	4	50	0	27,276	0	*x*	0
49	Francitas, *Jackson*	1	80	*y*	2,231	2,231	23[1]	23[1]
50	Ganado, *Jackson*	2	0	0	22,072	10,561	857[2]	410[1]
51	Garwood, *Colorado*	6	10	0	2,434	410	*x*	*x*
52	Gillock, *Galveston*	3	1,650	0	1,643,127	1,017,310	1,643[1]	1,017[1]
53	Greens Lake, *Galveston*	3	20	20	34,927	5,487	70[1]	3[1]
54	Greta, *Refugio*	6	5,414	1,050	22,445,724	2,572,347	15,750[1]	1,543[1]
55	Goose Creek, *Harris*	31	910	0	76,694,931	582,698	*x*	*x*
56	Hamman, *Matagorda*	3	390	0	743,036	552,049	2,220[1]	1,656[1]
57	Hankamer, *Liberty*	10	445	*y*	5,328,478	359,538	*x*	*x*
58	7,700 ft.	5		*y*		87,509	*x*	*x*
59	Hardin, *Liberty*	4	1,260	20	2,037,602	1,609,430	4,074[1]	3,218[1]
60	Hartzendorf, *Bee*	4	20	0	Prod. included with Pettus		*x*	*x*
61	Hastings, *Brazoria, Galveston*	5	5,100	0	15,798,141	6,876,577	6,319[1]	2,750[1]
62	Hawkinsville, *Matagorda*	3	50	0	3,616	0	*x*	*x*
63	Heyser, Calhoun, *Victoria*	3	3,600	0	4,728,673	3,035,739	2,675[1]	1,670[1]
64	High Island, *Galveston*	17	225	0	15,198,175	901,259	*x*	*x*
65	Hitchcock, *Galveston*	3	120	0	205,900	186,719	144[1]	131[1]
66	Hockley, *Harris*	16	10	0	23,404	Prod. depleted 1935	*x*	*x*
67	Holzmark, *Bee*	4	80	20	25,669	8,359	52[1]	16[1]
68	Hords Creek, *Goliad*	4	100	50	40,058	9,482	20[1]	4.6[1]
69	Hoskins Mound, *Brazoria*	35	10	0	31,755	Prod. depleted 1907	*x*	0
	Hull, *Liberty:*							
70	500 to 4,400 ft.	21	837	0	79,031,979	860,781	*x*	*x*
71	4,650 to 5,161 ft.	6		0	8,325,679	2,032,858	*x*	*x*
	Humble, *Harris:*							
72	700 ft.	34	3,300	0	110,123,797	545,850[1]	*x*	*x*
73	5,670 ft.	10		0	13,701,880	672,236[1]	*x*	*x*
74	Joes Lake, *Tyler*	2	320	0	354,453	280,143	710[1]	562[1]
75	Keeran, *Victoria*	7	320	40	854,192	186,823	513[1]	112[1]
76	Kubela, *Wharton*	3	195	0	114,654	90,990	115[1]	91[1]
77	La Belle, *Jefferson*	2	80	0	144,257	142,109	*x*	*x*
78	Lamar, *Aransas*	2	20	0	834	0	*x*	*x*
79	La Rosa, *Refugio*	1	400	0	46,522	46,522	23	23
80	League City, *Galveston*	1	80	0	6,959	6,959	14[1]	14[1]
81	Livingston, *Polk*	6	1,698	0	4,965,014	690,599	2,500[1]	280[1]
82	Lockridge, *Brazoria*	3	750	0	863,968	580,727	606	406[1]

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells					Oil-production Methods at End of 1938			Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1938
		During 1938		At End of 1938		Number of Wells				Average at End of		Gravity A.P.I. at 60° F.
	Completed to End of 1938	Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Flowing	Pumping	Gas Lift	Initial[4]	1937[4]	1938[4]	Weighted Average
44	60	4	0	51	2	6	45	0	100	*x*	pump	24
45	22	22	0	19	0	22	0	0	3,000		3,000	34.5
46	128	125	0	125	3	124	0	1	*y*		*y*	38.8
47	26	0	0	19	0	1	18	0	540	*x*	pump	28
48	2	0	0	0	0	0	0	0	1,100	pump	0	46
49	2	2	0	1	0	2	0	0	2,450		1,100–2,450	48
50	3	0	0	3	0	3	0	0	1,625	*e*2,200	750–1,850	26
51	4	0	0	1	0	1	0	0	1,225	*x*	*y*	44
52	116*y*	30	0	66	0	66	0	0	1,250	1,250	1,150	37.5
53	4	1	0	1	0	0	1	0	1,300	1,300	1,300	26.5
54	229	0	0	208	14	189	17	2	1,350	875	0–970	23.2 / 34.9
55	873	6	*y*	101	0	0	101	0	*x*	*x*	pump	25.5
56	17	10	0	17	0	14	0	3	800[4]	*x*	*x*	37
57	51*y*	6*y*	0	32	0	5	27	0	424	*x*	*x*	23.4
58			0	8	2	5	3	0		*x*	*x*	
59	113	96	0	106	1	103	3	0	900	*x*	*x*	36.3
60	1	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	*y*	45
61	612	159	0	612	0	609	0	3	2,175	2,100	*y*	31
62	1	0	0	0	0	0	0	0	200[4]	0	*y*	30.4
63	204	95	0	201	3	195	6	0	880	880	800	32.3
64	112	7	0	64	1	17	47	0	527	*x*	*y*	33
65	13	10	0	12	0	12	0	0	880	880	*y*	35.8
66	4	0	1	0	0	0	0	0	40	0	0	32
67	6	0	0	4	0	4	0	0	1,050	0	750–1,250	*y*
68	5	0	0	1	1	1	0	0	1,550	*x*	*y*	47.6
69	14	0	0	0	0	0	0	0	*x*	0	0	21.5
70	768	25	0	122	0	0	122	0	*x*	*x*	pump	30
71			0	80	0	12	68	0	530	*x*		38
72	1,736	22	*x*	299	0	8	291	0	*x*	*x*	pump	26.5
73			*x*		0			0	*x*	*x*	pump	*y*
74	14	9	0	14	0	14	0	0	1,425	1,425	1,425[1]	45.8
75	19	3	0	15	1	14	1	0	1,450	2,085	450–2,050	36
76	12*y*	4	0	12	0	9	3	0	1,500	*x*	pump to 1,500	23.5
77	1	0	0	1	0	1	0	0	*x*	*x*	*x*	40
78	1	0	0	0	0	0	0	0	*y*	*y*	*y*	*y*
79	13	13	0	13	0	13	0	0	850–1,150		850–1,150	39
80	3	3	0	3	0	3	0	0	1,100–2,100		1,100–2,100	42
81	101	1	0	90	1	45	38	7	700	*y*	*y*	40.7
82	38	13	0	38	0	38	0	0	2,100*y*	*e*2,880	2,000[1]	28

TABLE 1.—(*Continued*)

Line Number	Producing Rock								Deepest Zone Tested to End of 1938	
	Name	Age[e]	Depth, Average in Feet		Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
			Bottoms of Productive Wells	To Top of Productive Zone						
44	Mio, Heterostegina	Mio, Olig	4,460–7,624	2,275–5,707	Ss	24	15	Ds	Weches, Crockett	8,926 9,375[6]
45	Cockfield	Eoc	7,720–8,100	7,690–8,080	S	Por	30	D	Yegua	9,038
46	Yegua	Eoc	6,900	6,823	Ss	Por	20	A	Crockett	7,920
47	Mio, Mid-Olig, Frio	Mio, Olig	4,000–6,580	3,650–6,550	Ss	20	20	Ds	Vicksburg	7,293
48	Yegua	Eoc	4,706	4,643	S	Por	5	D	Crockett	5,425
49	Frio	Olig	7,708	7,416	Ss	Por	*x*		Frio	7,710
50	Marginulina	Olig	5,111	5,102	Ss	Por	5	D	Frio	6,544
51	Frio, Lower Olig, Cockfield	Olig, Eoc	4,410–6,203[3]	4,021–6,032	S	Por	12	D	Yegua	6,777
52	Frio	Olig	8,800	8,300	Ss	Por	12	DF	Frio	9,463
53	Mio	Pli, Mio	3,650–6,900	3,600–6,808	Ss	20	10	Ds	Frio	9,636
54	Catahoula, Heterostegina-Frio	Mio, Olig	2,100[8] 3,500 3,900	2,000 3,470 5,900	Ss	20, 33	20[3], 18	A	Vicksburg	7,461
55	Pli, Mio, Mid-Olig, Frio, Vicksburg	Pli, Mio Olig	4,600–5,894	1,000–5,875	SH	Por	40	D	McElroy	6,975
56	Frio	Olig	8,182 9,183 9,370		S	Por	10	Ds	Frio	9,575
57	Mio	Mio	2,700	2,650	Ss	*x*		Ds	Dibol	7,700
58	Frio	Olig	5,700–7,700		Ss	20		Ds	Jackson	
59	Yegua	Eoc	7,690	7,665	S	Por	20	D	Yegua	8,110
60	Cockfield (Pettus)	Eoc	3,651	3,642	SH	Por	9	A	Yegua	3,872
61	Frio	Olig	6,100	5,600	Ss	Por	60	D	Vicksburg	8,792
62	Mio	Mio	6,300	5,150	SH	Por	10	Ds	Oligocene	6,905
63	Heterostegina, Frio	Olig	6,118	5,473	Ss	25	25	D	Frio	6,505
64	Pli, Mio, Mid-Olig	Pli, Mio, Olig	4,960–6,710	3,625–5,022	Ss SH	Por	35*x*	Ds	Mid-Olig	7,179
65	Mio	Mio	5,134	5,118	Ss	Por	16	D	Frio	10,460
66	Cap rock, Frio	Pre-Ter, Olig	2,250	2,220	L, SH	Cav, Por	30	Ds	Yegua	7,481
67	Cockfield (Pettus)	Eoc	4,260	4,065	Ss	Por	*y*	NF	Yegua	4,458
68	Yegua	Eoc	4,575		SH	Por	10	MF	Cook Mt.	6,004
69	*y*	*y*	623	600	SH	Por	23	Ds	Salt	1,150*x*
70	Pli, Mio, Mid-Olig	Pli, Mio, Olig.	4,400	400	S	Por	63	Ds	Cook Mt.	6,845
71	Yegua	Eoc	5,806	4,400	SH	Por				
72	Cap rock, Mio, Olig	Pre-Ter, Mio, Olig	700[7]		L, S	Cav, Por	*y*		Cook Mt.	8,181
73	Mid-Olig, Jackson, Cockfield, Yegua	Olig, Eoc	5,670		SH	Por	400			
74	Carrizo Wilcox	Eoc	7,700	7,641	S	Por	20	Df*y*	Wilcox	8,180
75	Frio	Olig	7,011	5,597	S	15	10	MF	Vicksburg	7,852
76	Frio	Olig	4,719	4,590	Ss	Por	10	N	Jackson	8,888
	Marginulina						10			
77	Frio	Olig	8,217–8,670	8,200–8,600	Ss	25	45	Df	Frio	10,147
78	Frio	Olig	7,997		Ss	Por	*y*	*y*	Frio	9,000[4]
79	Frio	Olig	5,410	5,382	Ss	Por	*y*	*y*	Frio	6,907
80	Frio	Olig	8,700 9,104 9,304	8,695 8,944 9,236	Ss	Por	50±	D	Vicksburg	10,535
81	Cockfield	Eoc	4,276	4,180	Ss	25*x*	15	DF	Cockfield	5,596
82	Frio	Olig	6,365	6,342	Ss	20	23	AF	Vicksburg	8,698

[7] Cap Rock.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[a]	To End of 1938	During 1938	To End of 1938	During 1938
83	Lost Lake, *Chambers*	10	80	0	937,544	42,959	*x*	*x*
84	Louise, *Wharton*	5	1,614	0	2,213,821	469,138	*x*	117
85	Lovells Lake, *Jefferson*	1	80	0	50,920	50,920	*x*	*x*
86	Magnet, *Wharton*	3	380	40	456,888	325,104	320[1]	227[1]
	Manvel, *Brazoria:*							
87	4,016 ft.	8	692	0	14,082,688	3,219,165	7,041[1]	483[1]
88	5,160 ft.	8	870	0				
89	Markham, *Matagorda*	31	220	0	7,125,608	594,303	*x*	*x*
90	Markham (North), *Matagorda*	1	80	0	13,242	13,242	24	24
91	Mathis, *Live Oak, San Patricio*	15	0	100			*x*	*x*
92	Mauritz, *Jackson*	4	100	0	165,899	52,108	125[1]	39[1]
93	McFaddin, *Victoria*	8	570	100	454,822	374,177	1,232[1]	477[1]
94	McMurray, *Bee*	2	30	0	6,223	673	5[1]	0.5[1]
95	McNeill, *Live Oak*	5	100	0	219,590	25,022	885[1]	390[1]
96	Mineral, *Bee*	2	25	0	2,581	1,484	*x*	*x*
97	Mission River, *Refugio*	1	40	0	16,382	16,382	16	16
98	Moss Bluff, *Chambers, Liberty*	9	10	0	179,235	Prod. depleted 1933	*x*	*x*
99	Mount Lucas, *Live Oak*	8	500	4,000	224,466	19,330	11,250[1]	1,662[1]
	Mykawa, *Harris:*							
100	Shallow	9	270	0	3,453,988	92,214	*x*	568[1]
101	Deep	9				424,593	*x*	
102	Nash, Brazoria, *Ft. Bend*	13	120	0	1,665,226	740	*x*	*x*
103	Nome, *Jefferson*	3	1,040	0	1,126,137	499,314	676[1]	278[1]
104	Normanna, *Bee*	9	70	10	66,600	10,727	*x*	*x*
105	North	1	10	0	955	955	*x*	*x*
	North Dayton, *Liberty*							
106	1,200 ft.	34	100	0	800,000	0	*x*	*x*
107	4,800 ft.	11		0	1,524,191	33,947	*x*	*x*
108	Oakville, *Live Oak*	3	30	290	30,623	26,297	1,530	1,315
109	O'Conner-McFadden, *Refugio*	7	200	200	482,127	60,337	22,172[1]	2,760[1]
110	Old Ocean, *Brazoria*	5	1,040	0	2,509,492	1,783,783	12,545[1]	8,920[1]
111	Orange, *Orange*	26	400	0	32,445,476	203,057	*x*	*x*
112	West	2	220	0	287,508	287,508	201	201
113	Orchard, *Ft. Bend*	13	200	50	3,287,346	104,409	*x*	*x*
114	Palacios, *Matagorda*	2	80	0	80,999	47,534	243[1]	143[1]
115	Pettus, *Bee*	9	600	100	9,680,091	251,934	9,000[1]	75[1]
116	New, *Bee, Goliad, Karnes*	9	950	50	2,728,173	292,028	1,091[1]	58[1]
117	Pickett Ridge, *Wharton*	4	450	1,000	1,673,085	262,818	2,206[1]	679[1]
118	Pierce Junction, *Harris*	18	340	0	32,002,783	1,119,524	*x*	*x*
119	Placedo, *Victoria*	4	2,950	50	7,313,862	2,863,530	3,657[1]	240[1]
120	East	1	140	0	103,869	103,869	52[1]	52[1]
121	Pledger, *Brazoria*	7	20	1,100	17,068	Prod. depleted 1935	8,051	
122	Plummer, *Bee*	3	100	20	131,873	87,110	264[1]	174
123	Pt. Lavaca, *Calhoun*	5	280	30	354,311	10,224	10,000[1]	934[1]

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Producing Oil[b]	At End of 1938: Producing Gas[c]	Oil-production Methods at End of 1938, Number of Wells: Flowing	Pumping	Gas Lift	Pressure, Lb. per Sq. In.[d]: Initial[4]	Average at End of 1937[4]	Average at End of 1938[4]	Character of Oil, Approx. Average during 1938: Gravity A.P.I. at 60° F., Weighted Average
83	13	0	0	8	1	0	8	0	490	0	pump	22.4
84	44	0	0	35	2	27	8	0	730	248	247	26.3
85	3	3	0	3	0	3	0	0	*y*		*y*	38.5
86	29	10	0	23	1	23	0	0	*y*	*x*	900[1]	25.4
87	180	16	0	87	4	110	57	35	1,500	*e*1,500		24
88			0	83					2,200	*e*2,200		26
89	146	1	0	26	1	6	20	0	*x*	*x*	pump	23.2
90	2	2	0	2	0	2	0	0	1,400		1,100	34.5
91	6	0	*y*	*y*	*y*	0	0	0	935	*x*	*x*	*x*
92	2	0	0	2	0	2	0	0	*e*2,461	*e*2,461	*e*2,446	31
93	28	22	0	23	4	23	0	0	1,185[4]–1,725	*x*	100–1,375	21.2
94	2	0	0	2	0	0	2	0	570[5]	570	pump	47
95	11	1	0	5	4	4	1	0	1,150	*x*	*y*	44.3
96	3	0	0	1	0	0	1	0	100	0	pump	45
97	2	2	0	2	0	2	0	0	590–1,100		590–1,100	42.6
98	6	0	2	0	0	0	0	0	280	0	0	29.7
99	41	1	0	6	23	3	3	0	874–1,400	*x*	*x*	36
100	43	0	0	11	0	0	11	0	290	*x*	pump	28.2
101		0	0	22	0	0	22	0		*x*	pump	
102	25	0	0	1	0	0	1	0	800	*y*	*y*	19.9
103	43	4	0	41	2	38	3	0	2,640	2,450	2,538	28.6
104	8	0	0	5	1	3	2	0	150	*x*	200	38.8
105	1	1	0	0	1	0	0	0	*y*		*y*	46.5
106	52	0	0	0	0	0	0	0	*x*	*x*	0	24
107	13	3	0	9	0	0	9	0	400	*x*	pump	36
108	13	2	0	5	6	3	2	0	1,300	*x*	380, 60, 875	23
109	13	0	0	4	8	1	0	3	365	50	50	22.6
110	25	18	0	23	0	22	1	0	4,700	3,600–4,700	3,600–4,700	55
111	316	0	0	43	0	0	43	0	*x*	*x*	pump	23.8
112	25	25	0	22	0	22	0	0	*x*	*x*	*x*	35.8
113	34	3	0	15	0	5	10	0	375	*x*	*x*	35
114	4	2	0	2	0	2	0	0	*x*	*x*	*x*	53
115	88	0	0	39	4	0	39	0	236	0	pump	47
116	95	0	0	54	8	7	47	0	*x*	*x*	pump	47.5
117	44	3	0	31	3	29	2	0	900	*x*	700	25.2
118	272	10	0	89	0	18	71	0	355	*x*	pump	27.6
119	169	1	*x*	154	5	100	54	0	1,900	*x*	pump–650	25
												36.4
120	8	8	0	8	0	8	0	0	1,080	*x*	300–1,080	38.5
121	11	0			1	0	0	0	2,450	2,450	*x*	55.8
122	14	4	0	13	0	13	0	0	1,010	1,000	700	25
123	13	0	0	9	3	6	0	3	500	*x*	300–1,000	43

TABLE 1.—(*Continued*)

Line Number	Producing Rock: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
83	Frio	Olig	2,735 5,157	2,679 5,128	Ss	Por	33	Ds	Frio	7,471[6]
84	Frio	Olig	6,467 5,157	6,457 5,128	Ss	Por	20	NF	Vicksburg	8,271
85	Frio	Olig	7,724	7,716	S	31	8	Ds	Frio	7,732
86	Marginulina	Olig	5,662	5,551	Ss	Por	10	D	Frio	6,518
87	Mio	Mio	4,016	3,990	SH	Por	23	D	Vicksburg	7,957
88	Marginulina	Olig	5,700	5,000	Ss	Por	26	D		
89	Cap rock, Pli, Mio, Mid, Mio, Olig	Pre-Ter, Plio, Mio, Olig	4,350	936	L SH Ss	Cav, Por	$46x$	Ds	Vicksburg	6,056
90	Frio	Olig	7,730	7,705	Ss	30	5	AF	Frio	8,430
91	Mio	Mio	2,385	2,375	S	Por	10	ML	McElroy	5,526
92	Frio	Olig	5,703	5,634	Ss	Por	12	Ds	Vicksburg	7,408
93	Catahoula[3] Frio	Mio, Olig	2,470[3] 4,420	2,440 4,392	S	Por	24 10	AF	Vicksburg	7,025
94	Yequa	Eoc	4,284	4,267	S	Por	8	NF	Yegua	4,379
95	Hockleyensis, Cockfield	Eoc	4,992	4,434	S	Por	10	D	Cook Mt.	6,212
96	Cockfield (Pettus)	Eoc	3,650	3,545	S	Por	8	NF	Yegua	4,252
97	Frio	Olig	7,150	5,712	SH	Por	y	D	Vicksburg	9,225
98	Cap rock, Marginulina	Pre-Ter, Olig	830–5,800	800	SH	Cav, Por	33	Ds	Vicksburg	7,375
99	Catahoula,[3] Frio, Yegua	Mio, Olig Eoc	2,090 3,533 5,287	2,020 3,500 5,200	S SH	Por	28	D	Cook Mt.	6,789
100	Mio, Heterostegina	Mio, Olig	4,300	4,100	SH	Por	y	D	Whitsett	7,355
101	Frio	Olig	4,593	4,400	SH	Por	y	D		
102	Mio, Mid-Olig	Mio, Olig	4,825–5,677	3,700–5,644	S, SH	Por	$60y$	Ds	Vicksburg	6,800
103	Frio, Marginulina	Olig	6,058	6,005	SH	Por	10	Ds	Vicksburg	9,045
104	Hockleyensis	Eoc	3,676	3,500	SH	Por	17	D	Cook Mt.	5,038
105	Pettus (Cockfield)	Eoc	4,226	4,221	SH	Por	5	MF	Cockfield	4,272
106	Pli, Mio	Pli, Mio	1,200	400	Ss	Por	y	Ds	Yegua	6,077
107	Mio, Frio, Vicksburg	Mio, Olig	5,188	4,075	SH	Por	$32x$	Ds		
108	Cockfield (Pettus)	Eoc	2,828	2,136	Ss	Por	8	AF	Cook Mt.	4,502
109	Catahoula, Frio	Mio, Olig	3,100	3,075	SH	Por	20	DF	Frio	6,860
110	Frio	Olig	8,654 9,965 10,650	8,632	S	Por	22	D	Vicksburg	11,130
111	Pli, Mio, Mid-Olig, Frio	Pli, Mio, Olig	2,500	5,300	Ss SH	Por	$30x$	D	Frio	7,550
112	Frio	Olig	6,123	5,585	Ss	Por	y	D		
113	Mio, Frio Cockfield	Mio, Olig, Eoc	1,300 7,350	1,266	Ss	$20x$	30	Ds	Crockett	10,085
114	Frio	Olig	7,880	7,830	Ss	Por	10	D	Frio	8,843
115	Cockfield (Pettus)	Eoc	3,900	3,860	Ss	Por	19	DF	Queen City	7,569
116	Cockfield (Pettus)	Eoc	3,926	3,616	Ss	32	15	DF	Mt. Selman	7,569
117	Marginulina	Olig	4,710	4,690	S	Por	16	A	Hockleyensis	8,888
118	Mio, Frio, Vicksburg	Mio, Olig	3,800–4,800	3,780–4,780	Ss	Por	$130x$	Ds	Hockleyensis	7,165
119	Heterostegina, Frio	Olig	4,765–5,995	4,745–5,900	SH	Por	15	Af	Frio	7,242
120	Frio	Olig	6,382	6,370	SH	Por	15	Af		
121	Frio	Olig	6,800	6,650	S	Por	100	D	Frio	8,115
122	Cockfield (Pettus)	Eoc	4,277	3,036	Ss	Por	y	NF	Cook Mt.	4,256
123	Marginulina	Olig	6,250	6,240	S	Por	15	DF	Frio	6,780

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.	
			Oil	Gas[a]	To End o 1938	During 1938	To End of 1938	During 1938
124	Port Neches, *Orange* (3,150 ft.)	10	335	0	4,851,418	375,447	1,825[1]	120[1]
125	West (5,944 ft.)	2		0	47,074	41,266	24[1]	21
126	Raccoon Bend, *Austin* (3,490 ft.)	11	1,458	600	16,623,466	475,028	x	x
127	(4,120 ft.)	5	1,354		3,660,494	731,357	x	x
128	Ray, *Bee*	4	367	0	1,384,435	118,423	1,798[1]	x
129	Refugio, *Refugio*	11	1,025	y	x	397,000[1]	x	x
130	New	11	852	2,720	37,577,023	1,091,000[1]	x	17,110[1]
131	Fox	8	150			223,492[1]	x	
132	Rockland, *Jasper-Tyler*	11	20	0	30,858	0		
133	Rosslyn (Fairbanks), *Harris*	1	40	0	9,501	9,501	x	x
134	Sandy Point, *Brazoria*	2	260	20	170,467	118,883	119[1]	83[1]
135	Saratoga, *Hardin*	38	538	0	28,773,149	323,255	x	x
136	Sarco, *Goliad*	1	20	0	1,165	1,165	x	x
137	Satsuma, *Harris*	3	180	0	259,241	105,208	181[1]	74[1]
138	Schwab, *Polk*	5	90	0	128,616	22,705	x	x
139	Seabreeze, *Chambers*	3	120	120	133,639	103,575	1,174[1]	668[1]
140	Segno *Polk*	3	360	0	1,099,439	632,006	x	x
141	Deep	1		0	68,681	68,681	x	x
142	Silsbee, *Hardin*	3	690	0	1,039,105	602,877	2,864[1]	967[1]
143	Slick, *Goliad*	8	30	10	70,943	3,183	36[1]	x
144	Sour Lake, *Hardin*	37	946	0	78,992,425	438,889	x	x
145	South Houston, *Harris*	4	590	0	4,400,669	1,131,983	818[1]	566[1]
146	South Liberty, *Liberty*	14	345	0	15,447,177	188,900	x	x
147	Spindletop, *Jefferson*	38	580	0	51,364,967	205,567[1]	x	x
148	Deep	13		0	73,383,288	616,702[1]	x	x
149	Splendora, *Montgomery*	5	100	0	996	Abd. for oil 1935	x	x
150	Stratton Ridge, *Brazoria*	17	25	0	12,214	Prod. depleted 1933	x	x
151	Sugarland, *Ft. Bend*	11	1,165	0	27,480,645	1,222,435	x	x
152	Telferner, *Victoria*	2	30	40	26,722y	25,722	x	x
153	Thompsons, *Ft. Bend*	8	4,900	0	29,888,213	3,996,851	15,000[1]	2,000[1]
154	Tomball, *Harris*	6	8,400	1,200	11,397,985	2,576,578	22,796[1]	5,152[1]
155	Tom O'Conner, *Refugio*	5	6,600	0	11,001,983	4,345,963	6,601[1]	2,607[1]
156	Tuleta, *Bee*	7	125	0	1,678,458	135,038	169[1]	14[1]
157	Tulsita, *Bee*	1	0	10	Gas		x	x
158	Turtle Bay, *Chambers*	4	520	40	870,603	395,750	609[1]	277
159	Vanderbilt, *Jackson*	5	40	50	162,187	18,923	x	x
160	Voss, *Bee*	3	80	0	73,047	5,627	x	x
161	Webster, *Harris*	2	2,300	0	1,168,518	1,079,087	1,169[1]	1,080[1]
162	Weser, *Goliad*	3	100	0	2,556	0	x	x
163	West Beaumont, *Jefferson*	3	390	0	883,682	532,468	x	x
164	West Columbia, *Brazoria*	24	590	0	80,848,441	692,844	x	x
165	New	2		0	1,097,223	949,299	x	x
166								
167	West Ranch, *Jackson*	1	100	0	19,258	19,258	x	x
168	Willow Slough, *Chambers*	2	360	0	102,416	101,672	x	x
169	Wilson Creek, *Matagorda*	2	50	0	43,901	19,467	x	x
170	Withers, *Wharton*	3	2,138	900	1,727,807	928,321	864[1]	350[1]
171	(Five Corners)	3		600	54,408		1,538[1]	750[1]
172	Worth, *Bee*	4	50	0	27,275	0	x	x
173	Total		128,352y	15,750y	1,263,087,340	92,530,467	301,144x	86,049x

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Producing Oil[b]	At End of 1938: Producing Gas[c]	Oil-production Methods at End of 1938, Number of Wells: Flowing	Pumping	Gas Lift	Pressure, Lb. per Sq. In.[d]: Initial[4]	Average at End of 1937[4]	Average at End of 1938[4]	Character of Oil, Approx. Average during 1938: Gravity A.P.I. at 60° F., Weighted Average
124	18	0	0	18	0	5	13	0	980		pump–500	25
125	1	0	0	1	0	1	0	0	150		150	38.1
126	142	0	0	84	1	1	83	0	275	*x*	50	28.2
127	89	0	1	85	1	68	17	0	21,800	*x*	*x*	34.1
128	43	0	7	17	0	0	17	0	*e*1,755	0	pump	46
129	*x*	3	*x*	34	*x*	9	25	0	550	*x*	*y*	33
130	487*y*	30	*x*	100	*x*	89	11	0	1,700	*y*	1,050	39.5
131		1	*x*	18	*x*	13	5	0	*x*	*y*	600	38
132	8	0	0	0	0	0	0	0	*x*	*x*	*x*	21
133	0	1	0	1	0	1	0	0	1,800		1,800	39.3
134	8	2	0	8	0	8	0	0	2,200	2,025	2,000[1]	41
135	757*x*	0	0	236	0	0	236	0	*x*	*y*	pump	20
136	1	1	0	1	0	1	0	0	*x*		pump	35
137	10	1	0	9	0	9	0	0	2,400	2,400	2,400	44.5
138	4	0	0	3	0	3	0	0	1,400	*y*	*y*	48
139	8	1	0	3	5	3	0	0	3,600	3,600	3,600	50
140	36	9	0	32	0	31	1	0	1,450	1,400	1,000	39.5
141	8	8	0	8	0	8	0	0	950	950	950	36.8
142	38	11	0	35	2	35	0	0	575[4]	*x*	500[4]	44
143	5	0	0	1	0	1	0	0	550	*x*	500	46
144	782*x*	0	*y*	193	0	11	182	0	*x*	*x*	pump	20
145	98	0	0	94	0	67	27	0	1,600	*x*	1,000*y*–pump	25
146	326	3	0	43	0	3	40	0	50	*x*	pump	24
147	1,002	0	*x*	153	0	15	138	0	*x*	*x*	pump	25
148	360	12	*x*		0			0	400±	*x*	pump	26
149	1	0	0	0	0	0	0	0	2,000	*x*	*x*	65
150	4	0	1	0	0	0	0	0	*x*	*x*	*x*	29
151	71	0	*y*	51	2	40	11	0	*e*1,570	*y*	*y*	28.1
152	4	3	0	2	0	2	0	0	900	900	320–1,560	27.8
153	235	23	*y*	227	2	202	25	0	*e*2,430	*e*2,340	*x*	25
154	454	68	0	394	60	376	18	0	*e*2,490	*y*	*y*	41
155	369	142	0	364	1	364	0	0	1,040	880	880	35.5
156	91	0	*y*	23	7	9	14	0	792	*x*	pump	47
157	1	1	0	0	1	0	0	0	1,450*y*		1,450*y*	
158	33	6	0	30	2	26	4	0	2,400	*x*	*y*	32
159	2	0	0	1	0	0	1	0	500	0	pump	32
160	7	0	0	1	1	0	1	0	*x*	*x*	*x*	45
161	106	94	0	106	0	105	1	0	950	950	950	29
162	1	1	0	0	0	0	0	0	750	0	650	46.5
163	50	15	0	46	2	45	1	0	*x*	*x*	*x*	26
164	245	4	0	38	0	8	28	0	*x*	*x*	pump	20.1
165	55	45	0	54	0	50	4	0	625	625	625	28.1
166												
167	4	4	0	4	0	4	0	0	1,700		275–1,700	25.4
168	10	4	1	5	4	5	0	0	3,300	3,300	3,300	39
169	1	0	0	1	0	1	0	0	*x*	*x*	*x*	52
170	78	35	0	75	2	75	0	0	800	775	200–1,800	26.1
171	22	9	0	16	6	16	0	0	2,350	2,350	2,350	25.6
172	2	0	0	0	0	0	0	0	850		*x*	30.3
173	17,451	1,637	35*x*	8,451*x*	340	5,575	2,834	40*y*				

TABLE 1.—(*Continued*)

Line Number	Producing Rock								Deepest Zone Tested to End of 1938	
	Name	Age[e]	Depth, Average in Feet		Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
			Bottoms of Productive Wells	To Top of Productive Zone						
124	Pli, Mio, Frio	Pli, Mio, Olig	5,929	3,122	SHS	Por	40	DS	Vicksburg	7,667
125	Frio	Olig	5,942	5,920	SHS	Por	22	Ds		
126	Whitsett, McElroy	Eoc	3,490	3,280	Ss	25±	18	Df	Claiborne	7,061
127	Cockfield	Eoc	4,150	4,070	Ss	25±	35			
128	Cockfield (Pettus)	Eoc	3,944	3,888	SH	Por	15	DF	Yegua	4,253
129	Oakville, Catahoula	Mio	4,912	3,687	SH	Por	30	D		
130	Frio	Olig	6,562	6,325	SH	Por	30	D	Vicksburg	9,225
131	Marginulina	Olig	5,884	5,875	SH	Por	*y*	D		
132	Cockfield	Eoc	1,275	1,260	Ss	Por	10	MF	*y*	3,000*y*
133	Yegua	Eoc	6,956	6,947	Ss	Por	9	Af	Yegua	7,495
134	Frio	Olig	6,500	6,490	Ss	Por	7	D	Vicksburg	7,012
135	Lagarto, Mid. Olig, Cap rock	Mio, Pli, Olig, Pre-Ter	3,320	500	Ss, L	Por	*x*	Ds	Yegua	7,461[6]
136	Vicksburg	Olig	5,023	5,013	Ss	Por	*x*	D	Vicksburg	5,048
137	Cockfield	Eoc	6,835	6,825	S	Por	10	D	Yegua	7,520
138	Cockfield	Eoc	4,877	4,855	Ss	25*x*	9	NF	Yegua	5,533
139	Frio	Olig	8,150 8,490 8,850	8,100 8,400 8,700	Ss	25	20 17 40	Ds	Frio	9,637
140	Cockfield	Eoc	5,150	5,140	Ss	Por	10	D	Wilcox	9,154
141	Wilcox	Eoc	8,150	8,100	Ss	Por	30			
142	Cockfield	Eoc	6,950	6,900	S	Por	15±	Ds	Yegua	7,778
143	Cockfield	Eoc	4,404	4,240	Ss	Por	10	D	Yegua	4,580
144	Cap rock, Pli, Mio, Mid-Olig, Jackson, Up. Sal. Bay.	Olig, Pli, Mio	4,000*y*	900	SH	Por	*x*	Ds	Yegua	7,914
145	Mio, Frio	Mio, Olig	4,050–4,800	3,875–4,575	S	Por	20 40	Ds	Vicksburg	6,850[6]
146	Mio, Mid-Olig, Jackson, Yegua	Mio, Olig, Eoc	4,996	700	SH, Ss	Por	100*x*	Ds	Upper Saline Bayou	5,174
147	Cap rock, Pli	Pre-Ter, Pli	1,200	750	L SH	Cav, Por	*x*	Ds	Vicksburg	6,749
148	Mio, Mid-Olig, Frio	Mio, Olig	5,900	2,920	Ss	Por	69			
149	Cockfield	Eoc	5,840	5,835	Ss	Por	5	D	Cockfield	6,452
150	Mio	Mio	4,500	4,300	S	Por	10	Ds	Mid-Olig	7,624
151	Heterostegina, Marginulina, Frio	Olig	3,800	3,460	Ss	25±	60	Ds	Vicksburg	7,042
152	Olig	Olig	5,187	2,519	Ss	Por	8	Df	Frio	6,138
153	Mid-Olig, Frio	Olig	5,290	5,100	Ss	25	84	D	Vicksburg	8,539
154	Cockfield, Yegua	Eoc	5,555[3]–5,575	5,375–5,555	Ss	25*x*	9	DF	Yegua	7,438
155	Frio	Olig	5,969	5,820	Ss	Por	45	Af	Frio	8,174
156	Cockfield (Pettus)	Eoc	4,138–3,931	4,102–3,065	SH	Por	11	DF	Mt. Selman	6,062
157	Cockfield (Pettus)	Eoc	3,590	3,564	SH	Por	26	DF	Cockfield	3,598
158	Marginulina	Olig	6,615	6,600	Ss	Por	10	D	Frio	8,025
159	Frio	Olig	5,582	5,562	SH	Por	8	DF	Frio	7,042
160	Cockfield (Pettus)	Eoc	4,017	3,985	Ss	Por	5*y*	NF	Upper Yegua	4,308
161	Marginulina, Frio	Olig	6,050	5,750	Ss	Por	75±	D	Frio	8,452
162	Yegua	Eoc	4,812	4,802	SH	Por	7	MC	Yegua	5,052
163	Mio, Marginulina, Frio	Mio, Olig	6,756	4,560	SH	Por	10–25	DF	Vicksburg	8,501
164	Pli, Mio, Mid-Olig	Eoc, Pli, Mio	3,741	2,601	Ss	Por	250±			
165	Frio, Vicksburg	Olig	5,784	5,200	Ss	Por		DS	Vicksburg	6,306
166										
167	Greta (Frio)	Olig	5,127	5,086	Ss	Por	*y*	Ds	Frio	5,127
168	Frio	Olig	8,490–8,860	8,450–8,650	Ss	25	20	Df	Frio	9,056
169	Frio	Olig	9,978	9,925	Ss	Por	8	Df	Frio	9,978
170	Marginulina	Olig	5,560	5,545	S	Por	10	Df	Frio	7,244
171	Marginulina	Olig	5,550	5,540	Ss	Por	8	Df	Frio	6,511
172	Cockfield (Pettus)	Eoc	3,407		SH	Por	5	D	Pettus	3,705
173										

301 bbl. of oil per day on a 9⁄64-in. positive choke, with 1750 lb. per sq. in. on the tubing and 1950 lb. on the casing.

Lovell's Lake Field, Jefferson County.—This field produces from the Frio from 7716 to 7724 ft. The deepest zone tested was the Frio at 7732 feet.

TABLE 2.—*Summary of Drilling Operations on the Texas Gulf Coast in* 1938

Important Wildcats Drilled in 1938

	County	Survey and Tract	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
1	Bee	George A. Kerr, Hall Tract	3,598	Lagarto	Pettus (Cockfield)
2	Bee	J. M. Uranga Grant, Beck Tract	4,261	Lagarto	Pettus (Cockfield)
3	Bee	George Kerr, Courtney Tract	3,665	Lagarto	Pettus (Cockfield)
4	Brazoria	Breen, Copland and Osburne	10,700	Recent Alluvium overlying Beaumont	Frio
5	Chambers	State No. 1, Galveston Bay	5,967	Beaumont	Frio
6	Chambers	State No. 1-94, Galveston Bay	4,430	Beaumont	Miocene
7	Chambers	E. Douthit, Ogden Tract	7,525	Beaumont	Frio
8	Burleson	Eliza Sante, Coffield	6,181	Queen City	Edwards
9	Fort Bend	D. Scott, Well 58, Moore Tract	7,721	Beaumont	Yegua
10	Galveston	Houston Farms 2-D, Buckley	6,818	Recent Alluvium overlying Beaumont	Miocene
11	Galveston	Perry and Austin, Lobit Tract	9,106	Beaumont	Frio
12	Goliad	B. S. & F. No. 7, Drier Tract	3,515	Lagarto	Vicksburg
13	Goliad	J. Shearn, Weed Tract	5,048	Goliad	Vicksburg
14	Harris	J. Lindsey, Sowden Tract	5,805	Beaumont	Frio
15	Harris	Reels & Trobough, Barraco	3,818	Beaumont	Miocene
16	Harris	Reels & Trobough, Sanders	3,832	Beaumont	Miocene
17	Harris	R. Reinerman, Vollmer-Neiman	7,722	Lissie and Beaumont	Up. Saline Bayou
18	Harris	R. Reinerman, L. Lackner	8,096	Lissie and Beaumont	Yegua
19	Harris	A. Larson, Mills Tract	6,853	Lissie	Cockfield
20	Harris	S. Lewis, Look Tract	6,956	Lissie	Yegua
21	Harris	W. S. Powell, Goodykoontz	7,185	Lissie	Yegua
22	Jackson	Peter White, Faust Tract	2,675	Beaumont	Catahoula
23	Jackson	J. D. Newell, Weed Tract	7,468	Beaumont	Frio
24	Jackson	P. Green, Broughton	7,417	Beaumont	Frio
25	Jackson	Ramon Masquez, West Ranch	5,086	Beaumont	Marginulina
26	Jefferson	C. Hillibrant, Broussard Trust	7,723	Beaumont	Frio
27	Jefferson	S. A. Pace, McFaddin	3,855	Recent Alluvium overlying Beaumont	Miocene
28	Jefferson	B. Blackman, Broussard and Herbert	8,600	Beaumont	Frio
29	Liberty	J. Pleasant, Kirby Tract (C-21)	9,125	Lissie	Wilcox
30	Live Oak	O. Dacharity, McGriff 5-B	2,050	Oakville	Hockley
31	Live Oak	Parks-McNeill Estate	5,079	Goliad	Cockfield
32	Matagorda	T. & G. N. Sec. 7, Pierce Est. Fee	6,624	Beaumont	Frio
33	Matagorda	P. C. Yarborough, Cornelius	7,730	Beaumont	Frio
34	Matagorda	L. Goodwin, Bayshore Farms	9,275	Beaumont	Frio
35	Montgomery	W. S. Allen, Clary	4,739	Lissie	Cockfield
36	Orange	J. Dyson, Lutcher Moore No. 2	5,960	Beaumont	Frio
37	Orange	W. Dyson, Michel 7	5,576	Beaumont	Oligocene
38	Polk	I. & G. N. No. 15, Regan 2	8,168	Lissie	Wilcox
39	Refugio	Aldrete Grant, Rooke 1	5,920	Lissie	Frio
40	Refugio	Aldrete Grant, Schirner	6,328	Lissie	Frio
41	Refugio	Aldrete Grant, Rooke 2	5,370	Lissie	Frio
42	Refugio	Refugio Town, Mitchell 2-D	5,450	Lissie and Beaumont	Frio
43	Refugio	Lopez, Neiman 1	5,247	Beaumont	Frio
44	Victoria	Burham, Robertson 1	5,114	Beaumont	Frio
45	Victoria	M. de Leon Grant, Keeran No. 1	7,013	Lissie	Frio
46	Victoria	Benavides-Vanderberg and Hill	6,370	Beaumont	Frio
47	Victoria	E. Benavides, Henderson and Pickering	4,730	Beaumont	Heterostegina
48	Refugio	Refugio Town, Power 9	6,800	Lissie and Beaumont	Frio

North Markham Field, Matagorda County.—The North Markham field was discovered by the Ohio Oil Company's Cornelius No. 1 at 7730

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	Drilled by	Initial Production per Day		Choke, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Herbert Aid et al.	Spray	3	1/4 P.	1,050	1,250	Discovery, Tulsita
2	Dirks Bros.	56		5/32 P.	625	300	Discovery, North Normanna
3	Atlantic	18		Pump			Discovery, S. Tulsita
4	Harrison and Abercrombie	307		1/8 P.	4,200[1]	3,800[1]	New sand, Old Ocean
5	Std. of Texas and Salt Dome	650		1/4 P.		920	Discovery, Cedar Point
6	Standard of Texas	240		1/4 P.	0	100	New sand, Cedar Point
7	Salt Dome Oil Corp.		1.037	1/4 P.			Discovery, S. Anahuac
8	Red Bank Oil Co.	127		Pump			Discovery, Chreisman
9	Gulf Oil Corp.	44		1/4 P.	2,050	1,975	New sand, Orchard
10	Sun Oil Co.	29		1/4 P.	1,900	1,700	New sand, Green's Lake
11	Midwest Roy. Co.	301		9/64 P.	1,950	1,750	Discovery, League City
12	DeArman & Itinard	2	1 1/4	1/8 P. and 3/16 P.	1,790	830	New sand, Maets
13	Rual B. Swiger	8		Pump			Discovery, Sarco
14	West Production	5	0.625	5/16 P. and 3/16 P.	2,390	2,390	Discovery, Clear Lake
15	Stanolind O. & G. Co.	408	0.070	1/4 P.	425	380	New sand, Clinton
16	Stanolind O. & G. Co.	154		1/4 P.	270	230	Extension, Clinton
17	Jack Frazier	616	0.462	1/4 P.	1,510	1,100	Discovery, Eureka Heights
18	Jack Frazier	237	1.754	1/4 P.	1,900	1,650	New sand, Eureka Heights
19	Amerada-Stanolind	675	0.374	1/4 P.	2,400	1,100	Discovery, Fairbanks
20	Stanolind O. & G. Co.	250	0.450	1/4 P.	2,100	1,800	New sand, (Rosslyn) Fairbanks
21	Union Prod. Co.		12	1/4 P.	2,660	2,660	New sand, Fairbanks
22	Potter & Adams	270		3/16 P.	330	250	Discovery, Cordele
23	The Texas Company	78	3	11/64 P.	2,750	1,100	Discovery, Francitas
24	Wynn Crosby	288		3/16 P.	2,000	1,800	New sand, Francitas
25	Magnolia Petr. Corp.	132.5		1/4 P.	800	325	Discovery, West Ranch
26	Glenn H. McCarthy	105		9/64 P.	2,700	2,250	Discovery, Cheek
27	Shell Petr. Co.	605	0.191	1/4 P.	1,600	970	New sand, Clam Lake
28	Sun Oil Co.	1,066	78	4 1/2 drill stem	4,100	4,100	New sand, Labelle
29	Gulf Oil Corp.	43	4.5	1/4 P.	2,750	2,600	New sand, Cleveland
30	Simmons	144		7/32 P.	780	150	New sand, Oakville
31	Hantho-Nelson		3	1/4 P.	950	350	Discovery, Ramirena (McNeill)
32	Pierce Estate	241	0.096	3/16 P.	1,700	700	Discovery, McCrosky (Armour)
33	Ohio Oil Co.	135		1/8 P.	1,400	865	Discovery, N. Markham
34	Sun Oil Co.	151	3.02	1/8 and 11/64 P.	4,900	5,100	New sand, Palacios
35	Housh-Thompson	36	44[2]	3/8 P.	1,755	1,650	Discovery, West Conroe
36	Union Prod. Co.	587	0.186	1/4 P.	875	900	New sand, Orange
37	Red Bank Oil Co.	127	0.210	3/16 P.	1,150	925	New sand, Orange
38	Gulf Oil Corp.	632	0.569	1/4 P.	1,350	1,200	New sand, Segno
39	Coronado	114		1/8 P.	1,400	775	New sand, La Rosa
40	Rutherford	96		1/8 P.	925	750	New sand, La Rosa
41	Coronado Expl. Co.	25		1/4 P.	2,190	2,160	Discovery, La Rosa
42	Morgan	135		1/4 P.	900	500	New sand, Refugio (Bonnie View)
43	Rutherford & Barnsdall	Spray	92.5	[2]	2,225	2,125	Discovery, Woodsboro
44	W. V. Bowles	40		7/32 P.	1,050	800	Discovery, E. Telferner
45	Barnsdall	94		3/32 P.	2,650	1,875	Discovery, Keeran
46	Stanolind O. & G. Co.	130		1/8 P.	2,150	1,900	New sand, East Placedo
47	Stanolind O. & G. Co.		20	[2]	1,840	1,840	New sand, East Placedo
48	Union Prod. Co.	140		1/4 P.	2,450	2,425	New sand, Refugio

[1] Estimated. [2] Open flow.

Number of wells drilling Dec. 31, 1938 .... z
Number of oil wells completed during 1938 1,637
Number of gas wells completed during 1938 .... 340y
Number of dry holes completed during 1938 .... z

ft. in the Frio for 135 bbl. of oil on a ⅛-in. choke, with 865 lb. per sq. in. tubing pressure and 1400 lb. casing pressure. The Frio was tested at 8430 feet.

Mission River Field, Refugio County.—The Mission River field produces from Oligocene sands at 5712 and 7150 ft. The Vicksburg was tested at 9225 feet.

North Normanna Field, Bee County.—This field was discovered by Dirks Bros. No. 1 Beck at 4261 ft. in the Pettus sand (Cockfield). As yet it does not promise a very large production.

East Placedo Field, Victoria County.—The East Placedo field produces from the Frio at 6370 ft. It was discovered by Stanolind Oil and Gas Company's Vanderberg and Hill well for 130 bbl. of oil on a ⅛-in. choke.

Rosslyn Field, Harris County.—The Rosslyn field was discovered by Stanolind Oil and Gas Company's Looke well at 6956 ft. in the Yegua, for 250 bbl. of oil and 450,000 cu. ft. of gas on an ⅛-in. choke. It appears to be an extension to Fairbanks rather than a new field.

Sarco Field, Goliad County.—This field was discovered by Rual B. Swigers' Weed No. 1 at 5048 ft. in the Vicksburg for a small producer, and as yet does not show much promise.

Segno (Deep) Field, Polk County.—The Gulf Oil Corporation's Regan No. 2 was completed in the Wilcox at 8168 ft. for 632 bbl. of oil with 569,000 cu. ft. of gas on a ¼-in. positive choke, which started development of the Wilcox at Segno. The Wilcox production in the Texas Gulf Coast area is causing considerable play in the older fields.

West Ranch Field, Jackson County.—Magnolia Petroleum Company's No. 1 West Ranch discovered this field in the Marginulina at 5086 ft. The well produced 132 bbl. of oil on a ¼-in. positive choke with 325 lb. per sq. in. tubing pressure and 800 lb. casing pressure. This well tested the Frio at 5127 feet.

Acknowledgments

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Oil and Gas Development and Production in North Texas for the Year 1938

By H. B. Fuqua,* Member A.I.M.E., and B. E. Thompson†

(New York Meeting, February, 1939)

The area discussed herein, commonly known as the North Texas district, embraces the following 10 counties: Archer, Baylor, Clay, Cooke, Foard, Hardeman, Knox, Montague, Wichita and Wilbarger. It is underlain by two major structural features. The northernmost portion of the district, including Cooke, Montague, northern Clay, Wichita, Wilbarger, Foard and Hardeman Counties, is underlain by the system of buried mountains known as the Red River uplift, which is parallel to and closely related to the Wichita-Amarillo uplift of Oklahoma and the Texas Panhandle. While the presence of a great majority of the numerous oil fields of the area is traceable to this feature, the production in Archer, southwestern Clay and southeastern Baylor Counties is due to the influence of what is known as the Cisco arch (so called because of its influence on Cisco deposition), the axis of which extends in a northwest-southeast direction across southwestern Wichita County into Archer County.

Developments during 1938

Important discoveries in the district were considerably more numerous and of more economic importance than for several years. In addition to a number of small, relatively unimportant discoveries and to the usual local extensions to the various producing fields in the several counties, at least eight fields, most of them apparently of considerable areal extent and importance, were found.

The Helmerich and Payne, Incorporated and Blackwell Oil and Gas Company No. 1 Wilson, 4 miles southeast of the town of Holliday, in north central Archer County, encountered a pay of Strawn age at a depth of 3841 to 3858 ft., and was completed for an initial production of 1952 bbl. This well opened a new deep pool in the K. M. A. producing zone 8 miles southeast of the K. M. A. production. Subsequently an additional deeper horizon, also of lower Strawn age, was discovered by wells that failed to yield commercial oil from the horizon of the discovery well.

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* Gulf Oil Corporation, Fort Worth, Texas.

About 4 miles east of the above-mentioned discovery, Fain-McGaha drilled their No. 1 Wilson (McCrory) "G" to a depth of 4760 ft. This test was completed for an initial production of 280 bbl. from a limestone pay, 4727 to 4760 ft., which is of undifferentiated Pennsylvanian age (lowermost Strawn or Bend).

A mile east of the town of Scotland, in east central Archer County, near the Clay County line, Adams Oil and Gas Co. completed its No. 1 Moer for an initial production of 115 bbl. daily in a pay of Strawn age, which is somewhat lower stratigraphically than the K. M. A. deep horizon of Wichita County. No additional development has taken place, to date, in the vicinity of this discovery.

In Baylor County, 8 miles east of Seymour, British American Oil Producing Company's No. 1 Green was completed in Canyon limestone pay, 2580 to 2605 ft., for an initial production of 158 bbl. of oil with considerable water. This well opened a new pool, the second in the history of development in the county.

In northeastern Cooke County, 11 miles northeast of the town of Gainesville, the Sinclair Prairie Oil Company's No. 1 Best was completed in a lower Strawn sand, 4887 to 4900 ft., for an initial production of 912 bbl. daily. This test is well down in the Marietta syncline, which flanks the Criner Hills uplift of Love County, Oklahoma, to the southwest

TABLE 1.—*Oil and Gas Production in North Texas*

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.		Number of Oil and/or Gas Wells				
							Completed to End of 1938	During 1938		At End of 1938	
			Oil	Gas[a]	To End of 1938	During 1938		Completed	Abandoned	Producing Oil[b]	Producing Gas[c]
1	Deep production, *Archer*	7	2,000	0	182,297	180,778	44	42	0	44	0
2	All other fields, *Archer*	26	23,300	0	112,629,972	3,799,970	6,626	77	139	3,814	0
3	Portwood, *Baylor*	14	600	0	4,016,271	462,769	185	0	0	165	0
4	Petrolia,[1,2] *Clay*	36	1,100	4,000	7,176,524	458,527	755	106	3	552	39
5	Worsham, *Clay*	15	400	0	320,616	84,208	10	2	0	6	0
6	Bruhlmeyer, *Cooke*	3	900	0	2,455,597	526,071	129	2	2	127	0
7	Walnut Bend,[3] *Cooke*	1	100	0	17,887	17,887	2	2	0	2	0
8	Miscellaneous, *Cooke*	13	3,300	100	12,715,623	1,185,948	814	105	3	809	2
9	Johnson, *Foard*	6	0	400	1,194,573	187,219	14	2	0	9	3
10	Thalia, *Foard*	12	0	0	289,739	17,420	13	0	0	7	4
11	All fields, *Montague*	16	6,000	500	28,304,212	1,904,311	1,041	55	0	915	21
12	Deep production, *Wichita*	7	25,000[4]	0	5,809,489	4,809,427	841	741	0	841	0
13	All other fields, *Wichita*	27	41,300	0	305,540,746	5,482,709	11,353	131	165	6,531	0
14	All fields, *Wilbarger*	26	10,000	0	65,289,931	3,029,481	1,988	41	43	1,362	0
15	Total		114,000	5,000	545,943,477	22,146,725	23,815	1,306	355	15,184	69

[a] Footnotes to column heads and explanation of symbols are given on page 240.

[1] In Petrolia field total gas production was: 99,041,621 M cu. ft. to end of 1938; production for 1937 was 286,300 M cu. ft. and 233,858 M cu. ft. for 1938.

[2] Includes a few isolated producers with negligible production in other parts of county.

[3] Initial pressure 2360 lb. per sq. in.; average porosity of pay 20 per cent.

[4] Part of this acreage productive in shallow zones is again included in "Wichita County—all other fields" and is duplicated in total proven acreage of district.

and extends in a southeast direction into Texas. The same operator's No. 1 Putnam, slightly north of the discovery well, failed to make a commercial producer in the discovery sand and was drilled to a depth of 6055 ft., penetrating Ordovician sediments from 5198 ft. to the total depth. However, it failed to obtain production in the lower levels and was plugged and abandoned.

In Montague County, immediately west of the town of Nocona, the Rogers and Rogers (formerly Youngblood and Foree et al.) No. 1 Burnett was completed in a lower Strawn sand pay from 4645 to 4654 ft. for an initial production of 648 bbl. Several showings of oil in the section were reported and it is entirely possible that an oil field with several productive horizons will be developed in this vicinity.

In Wichita County, just north of the town of Holliday (Archer County), the King Oil Co. and Madden and Goldsmith No. 1 Jackson was drilled to a total depth of 4537 ft. Showings of oil were encountered in the lower Strawn section but it failed to make a commercial producer. It was plugged back and completed for an initial production of 500 bbl. per day in a Canyon (Pennsylvanian) pay from 2641 to 2715 feet.

In southeast Wichita County, near the south limits of the city of Wichita Falls, the Petroleum Producers Co. and Continental Oil Co. No. 1 State Insane Asylum was drilled to a depth of 5405 ft. and plugged back to 5365 ft. Ordovician dolomite (Ellenburger) was encountered at a depth of 5266 ft. and, while pay records on this well are somewhat confused, the well appears to be producing oil from undifferentiated

TABLE 1.—(*Continued*)

	Oil-production Methods at End of 1938		Character of Oil. Approx. Average during 1938	Producing Formation							Deepest Zone Tested to End of 1938	
	Number of Wells		Gravity A.P.I. at 60° F.			Depth, Average in Feet						
Line Number	Flowing	Pumping	Weighted Average	Name	Age[e]	To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
1	44	0	41.0	Strawn zone	Pen	4,000	SL	*x*	*y*	*y*	Cam-Ord	5,270
2	0	3,814	38.5	Numerous	Pen	1,300	SL	*x*	10±	ML	Cam-Ord	5,750
3	0	165	36.5	Swastika sand	Pen	1,400	S	*x*	10±	ML	Pen (Strawn)	4,265
4	0	552	36.0	Numerous	Per, Pen	1,500	S	*x*	10±	A	Cam-Ord	4,289
5	6	0	38.0	Worsham pay	Pen	3,850	LS	*x*	50±	D	Pen (Bend)	5,127
6	0	127	41.0	Bruhlmeyer sand	Pen	2,000	S	*x*	15	AD	Pen	2,500
7	2	0	35.3	Strawn sand	Pen	4,900	S	20%	25	*y*	Cam-Ord	6,055
8	0	809	35.0	Several	Pen-Ord	1,200	SL	*x*	10±	AD	Pre-Cam	3,790
9	9	0	43.0	Johnson lime	Pen	3,800	LS	*x*	30±	AF	Pre-Cam	5,003
10	0	7	39.0	Thalia sand	Pen	2,000	SL	*x*	22±	D	Pre-Cam	2,550
11	0	915	29.0	Numerous	Pen	1,000	SL	*x*	20±	AD	Pre-Cam	2,915
12	700*y*	141*y*	43.0	K.M.A. (deep)	Pen	3,800	LS	*x*	100±	AM	Cam-Ord	5,430
13	0	6,531	39.0	Numerous	Per-Pen	1,500	SL	*x*	20±	AM	Pre-Cam	3,502
14	0	1,362	37.0	Numerous	Per-Pen	1,800	SL	*x*	20±	AD	Pre-Cam	3,007
15	761	14,423										

lower Pennsylvanian and Ellenburger beds between 5128 and 5365 ft. This well was completed for an initial production of 136 bbl. daily.

General Comments

Acid treatment of wells, which has played an important part in the development of certain limestone areas of the district, was not practiced to a great extent during the year 1938. However, it appears at this time that a number of the deeper discoveries discussed above, including those

Table 2.—*Summary of Drilling Operations in North Texas*

Important Wildcats Drilled in 1938

	County	Location			Total Depth, Ft.	Surface Formation
		Fee	Survey	Sec-Blk.		
1	Archer	Wilson No. 1	ATNCL	25	3,858	Pen
2	Archer	Wilson (McCr) No. 2	ATNCL	25	4,363	Pen
3	Archer	Wilson No. 2	ATNCL	25	5,270	Pen
4	Archer	Moer No. 1	Cl. & Pl.	21-3	4,165	Pen
5	Archer	Wilson (Mc) G-2	ATNCL	44	4,760	Pen
6	Wichita	Jackson No. 1	Denton Co. Sch.	20	4,537	Pen
7	Wichita	St. Ins. Asyl. No. 1	Cher'ke Co. Sch.	1	5,405	Pen
8	Baylor	Green No. 1	T. & NO	215	2,635	Pen
9	Baylor	Portwood No. 1	TE & L.	3144	5,560	Pen
10	Clay	Edwards No. 1	S. J. Beldon	Abst. 12	6,354	Pen
11	Montague	Burnett No. 1	J. Lenow	Abst. 433	4,656	Pen
12	Cooke	Best No. 1	T. Toby	Abst. 1054	4,900	Cre
13	Cooke	Putnam No. 1	T. W. Wood	Abst. 1089	6,055	Cre
14	Cooke	Voth No. 2	W. W. Fulton		1.793	Cre
15	Wilbarger	King-Waggoner No. 1	H. & T. C.	63 14	2,899	Per
16	Wilbarger	N.N. Waggoner No. 126	H. & T. C.	42 4	3,765	Per

Important Wildcats Drilled in 1938

	Deepest Horizon Tested	Drilled by	Initial Production per Day	Pressure, Lb. per Sq. In.		Remarks
			Oil, U. S. Bbl.	Casing	Tubing	
1	Strawn (KMA)	Helmerich-Payne-Blackwell	1,952	y	y	Opened new deep pool
2	Strawn L	Blackwell-Helmerich-Payne	960	y	y	Opened deeper horizon
3	Cam-Ord	Helmerich-Payne-Blackwell	1,104	625	150y	Tested Ellenburger; P. B. Strawn
4	Strawn L	Adams Oil and Gas	115	140y	y	Opened new deep pool
5	Bend (?)	Fain-McGaha.	280	y	y	Probable Bend production
6	Strawn L	King Oil and Madden and Goldsmith	500	y	y	Test lower Strawn; P. B. Canyon
7	Cam-Ord	Petr. Prod. and Continental		650	y	Production (probably from lower Strawn) and Ellenburger
8	Canyon	British American	158	90	y	Opened new pool
9	Cam-Ord	Wilcox Oil and Gas	Dry			Top Ellenburger 5460
10	Cam-Ord	Walter H. Gant	Dry			Top Ellenburger 5995
11	Strawn L	Youngblood-Foree	648	y	y	Deep pool opener
12	Strawn L	Sinclair-Prairie	912	660 (S.I.)	40	Deep pool opener
13	Ordovician	Sinclair-Prairie	Dry			Ord. topped at 5198
14	Cam-Ord	Whitfield-Pearson-Grimes	432	y	y	Opened deeper horizon
15	Pen-(Cisco)	Phillips Petr. Co.	172	y	y	New pool-new sand
16	Pen-Ord Contact	Phillips Petr. Co.	344			New horizon-old pool

in Archer and in Baylor Counties, will tend to revive the practice of acidizing as the development progresses.

During the years preceding 1938, it is doubtful whether the restrictions of proration had any great effect upon the production of the district. However, because of the large flush production developed during that year, it is believed that the allowed production of some of the fields in the district, particularly K. M. A. and the new Walnut Bend production of Sinclair Prairie in Cooke County, is at this time considerably below that which they could produce without restrictions.

Outlook for 1939

During the year 1938 there were 1306 oil wells completed in the district as compared to 718 during the preceding year. Of this number, 770 were in the 3800-ft. producing horizon in the K. M. A. field. Production of the K. M. A. field was approximately 5,000,000 bbl., as compared to a production of about one-half million barrels during the year 1937. Production of the North Texas district increased from 20,465,105 bbl. in 1937 to 22,146,725 bbl. during 1938. Therefore, the inference is obvious that the production of the district as a whole would have decreased materially during the year 1938 had it not been for the intensive development carried on at K. M. A. Since activities at K. M. A. will be greatly decreased during the coming year, and since it appears, at this time, that development in other newly discovered areas will be at a very moderate pace, it is not anticipated that the production of the district for the year 1939 will greatly exceed that of the year just passed.

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Oil and Gas Development in North Central Texas for 1938

By H. W. Imholz*

Active interest in the North Central Texas area centered in the development of the Palo Pinto limestone-producing zone, near the town of Avoca, in the northeast part of Jones County. This producing horizon was discovered in 1937, in the Iron Mountain Oil Company's well No. 1 Olander, in sec. 196, B.B.B. & C. survey, at 3238 to 3250 ft. During the development of this pool, it was generally referred to as the Avoca pool. As a second pool has been discovered in the same producing zone, also near the town of Avoca, the writer has taken the liberty of changing the name of the original Avoca pool to Avoca-Olander pool.

Forty producers had been drilled in the Avoca-Olander pool by the end of 1938; their initial ranged from 28 to 300 bbl. per hour.

Stimulus was given to the interest in the development of the Palo Pinto limestone when the Ungren-Frazier No. 1 Griffin, in sec. 199, B.B.B. & C. survey, Jones County, found the limestone from 3225 to 3250 ft., with an initial production of 931 bbl. per day. (This new pool has been given the name of Avoca-Griffin pool, by the writer.) The best well to be completed, up to the present time, is the Bert Fields No. 1 Taylor in sec. 199, B.B.B. & C. survey, which had an initial production of 748 bbl. in 3 hours.

The Owen-Snebold No. 1 McKeever in sec. 158, B.B.B. & C. survey, in northwest Shackelford County, added to the interest in the Palo Pinto limestone when it extended the Ivy pool with a well in the Palo Pinto limestone from 3145 to 3183 ft., and was estimated good for 6,000,000 cu. ft. of gas and 6000 bbl. of oil per day.

During 1938, Stonewall County obtained its first commercial producer when the Stonewall Oil Co. in No. 1 Parriott discovered the Palo Pinto limestone saturated from 5169 to 5176 ft. and tested 371 bbl. per day.

Two new producing horizons were discovered about 2 miles east of the old Noddle Creek pool, Jones County; the first, the Humble Oil & Refining Co. No. 1 Irvin, in sec. 48, block 18, T. & P. R. R. Co. survey, which had saturated limestone from 2550 to 2567 ft. and was good for 100 bbl. per day; the second, in the Humble No. 1 Horton, sec. 40, which

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* Consulting Geologist, Abilene, Texas.

TABLE 1.—*Oil and Gas Production in North Central Texas*

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres	Total Oil Production, Bbl.	
			Oil	To End of 1938	During 1938
1	Bull-Allcorn, *Brown*	11	100	126,035	3,774
2	Byler, *Brown*	12	290	835,117	10,775
3	Byrd Store, *Brown*	18	250	398,392	7,091
4	Childress, *Brown*	11	180	826,043	44,058
5	Clark-Buffalo, *Brown*	11	460	775,320	14,708
6	Cross-Cut, *Brown*	17	2,300	6,125,155	117,845
7	Fry, *Brown*	13	940	7,710,705	91,939
8	George, *Brown*	11	200	757,240	25,366
9	Smith-Ellis, *Brown*	12	450	2,253,601	48,678
10	Stover, *Brown*	12	1,500	7,006,463	158,344
11	Other Fields, *Brown*		5,595	2,432,769	61,620
12	Total Brown County		12,265	29,246,840	584,198
13	Baum, *Callahan*	13	500	864,654	15,612
14	Hatchett, *Callahan*	11	375	1,341,494	58,378
15	Isenhour, *Callahan*	15	600	2,133,345	50,501
16	Moutray, *Callahan*	12	400	2,422,978	92,045
17	Other Fields, *Callahan*		9,515	6,970,848	244,617
18	Total Callahan County		11,390	13,733,319	461,153
19	Burkett (Shallow), *Coleman*	14	850	2,257,955	70,769
20	Burkett (Deep), *Coleman*	8	200	676,678	14,618
21	Dibrell, *Coleman*	11	170	381,367	40,026
22	Eastland, *Coleman*	10	270	1,998,818	42,944
23	Jennings, *Coleman*	11	135	461,050	10,758
24	Overall, *Coleman*	12	200	1,239,588	43,965
25	Santa Anna, *Coleman*	16	150	454,334	21,218
26	Stewardson, *Coleman*	8	200	403,156	18,338
27	Other Fields, *Coleman*		985	1,820,222	92,982
28	Total Coleman County			9,693,168	355,618
29	Sipe Springs, *Comanche*	19	800	1,411,429	19,417
30	Other Fields, *Comanche*		y	4,130	4,130
31	Total Comanche County			1,415,559	23,547
32	Desdemona, *Eastland, Erath, Comanche*	20	6,175	22,985,291	161,508
33	Hillburn, *Eastland*	19	400	1,102,103	9,055
34	Mangum, *Eastland*	16	300	847,881	55,242
35	Pioneer, *Eastland*	19	1,400	5,442,207	98,112
36	Ramsour, *Eastland*	13	250	1,456,606	31,533
37	Other Fields, *Eastland*		27,660	63,976,230	698,166
38	Total Eastland County		30,010	72,825,027	892,108
39	Howard, *Fisher*	4	40	68,331	21,616
40	Royston, *Fisher*	10	2,880	9,537,623	726,910
41	Rotan (Robinson), *Fisher*	2	640	492,722	391,834
42	Rotan (Bennett), *Fisher*	1	80	17,625	17,625
43	Total Fisher County		3,640	10,116,301	1,157,985
44	Moody, *Haskell*	11	40	103,210	5,648
45	Other Fields, *Haskell*			29,171	29,171
46	Total Haskell County		40	132,381	34,819
47	Sandy Ridge (Higgs), *Jones*	13	450	237,420	44,560
48	Dorsey-King, *Jones*	13	600	2,712,458	441,120
49	Jennings-Leuders, *Jones*	4	160	505,420	122,500
50	Noodle Creek, *Jones*	11	1,030	6,494,031	188,794
51	Guitar (Hawley), *Jones*	2	400	565,254	176,874
52	Sayles, *Jones*	6	640	988,610	373,291
53	Avoca-Olander, *Jones*	2	640	409,015	367,939
54	Avoca-Griffin, *Jones*	½	640	4,540	4,540
55	Lewis, *Jones*	2	300	246,018	227,449
56	Steffens, *Jones*	1	160	21,266	21,266
57	Irvin (Noodle Creek), *Jones*	1	1,200	36,713	36,713
58	Other Fields, *Jones*		300	122,366	34,408
59	Total Jones County		6,520	12,343,111	2,039,454
60	Cook, *Shackelford*	13	1,460	15,213,037	635,401
61	Frye, *Shackelford*	13	115	311,539	6,193
62	Hope, *Shackelford*	15	220	1,219,052	21,803
63	Ibex, *Shackelford*	17	1,240	2,411,944	37,860
64	Bluff Creek, *Shackelford*	8	940	2,718,516	480,879
65	Newell, *Shackelford*	13	640	770,600	44,644
66	Petroleum Producers, *Shackelford*	9	100	138,438	8,761

TABLE 1.—(*Continued*)

Line Number	Average Oil Production per Acre	Number of Oil and/or Gas Wells at End of 1938	Character of Oil, Approx. Average during 1938		Producing Rock				
	To End of 1938	Producing Oil[b]	Gravity A.P.I. at 60° F. Maximum	Gravity A.P.I. at 60° F. Minimum	Name	Age[e]	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Structure[g]
1	1,260	13	40	37	Fry sand	Pen	1,150	S	ML, N
2	2,879	28	40	38	Fry sand	Pen	1,300	S	ML, N
3	1,593	8	38	37	Bend	Pen	2,450	L	A
4	4,589	62	38	33	Childress sand	Pen	800	S	ML, N
5	1,685	34	44	40	Fry sand	Pen	1,150	S	ML, N
6	2,662	206	41	39	Cross cut sand	Pen	1,200	S	ML, N
7	8,203	117	44	40	Fry sand	Pen	1,300	S	ML, N
8	3,786	42	40	38	Fry sand	Pen	1,300	S	ML, N
9	5,008	51	42	40	Fry	Pen	1,300	S	ML, N
10	4,671	203	42	40	Blake	Pen	1,200	S	ML, N
11									
12									
13	1,729	36	40	38	Cross Plains	Pen	1,700	S	ML, N
14	3,577	98	39	38	Moutray	Pen	400	S	M, L
15	3,555	143	38	36	Isenhour	Pen	700	S	M, L
16	6,057	114	39	36	Moutray	Pen	750	S	M, L
17		960							
18		1,351							
19	2,656	180	35	34	Burkett	Pen	400	S	M, L
20	3,383	34	43	40	Cross Cut	Pen	1,550	S	ML, N
21	2,243	11	44	40	Gwinnup	Pen	1,900	S	ML, N
22	7,402	31	43	41	Gwinnup	Pen	2,000	S	ML, N
23	3,415	25	40	38	Fry	Pen	1,150	S	ML, N
24	6,197	24	44	40	Strawn	Pen	2,300	S	A
25	3,028	8	40	38	Fry	Pen	1,500	S	ML, N
26	2,016	25	40	38	Fry	Pen	1,450	S	M, L, N
27	1,848	59							
28		397							
29	1,764	85	37	34	Strawn	Pen	300	S	A
30		28							
31		113							
32	3,722	96	44	34	Desdemona	Pen	2,750	S	A
33	2,755	2	39	35	Bend	Pen	3,100	L	MN
34	2,826	46	42	33	Strawn	Pen	1,200	S	N
35	3,887	58	42	40	Caddo	Pen	2,450	L	AF
36	5,826	9	40	38	Bend	Pen	3,600	S	N
37	2,312	393							
38		508							
39	1,708	2	37	35		Pen	3,670	L	A
40	3,311	112	41	38	Saddle Creek	Pen	3,100	L	A
41	770	28	40	37	Camp Colorado	Pen	3,500	L	M, N
42	221	2	40	37	Camp Colorado	Pen	3,600	L	M, N
43		144							
44	2,580	6	37	36	King	Pen	1,800	S	N
45		5							
46		11							
47	527	22	38	37	Bluff Creek	Pen	1,900	S	N
48	4,520	103	42	37	6 Cisco sands	Pen	1,900–2,300	S	A
49	3,158	21	40	37	King	Pen	2,040	S	A
50	6,305	85	39	38	Camp Colorado	Pen	2,500	L	MCA
51	1,413	66	38	37	Cook	Pen	2,000	L	A
52	1,544	43	41	40	Cook	Pen	1,950	S	N
53	639	40	40	38	Strawn-Canyon	Pen	3,200	L	A
54		3	40	38	Bluff Creek	Pen	1,900	S	A
55	383	45	38	37	Bluff Creek	Pen	1,900	S	ML, N
56	133	16	38	37	Bluff Creek	Pen	1,900	S	ML, N
57		5	40	38	Swastika	Pen	2,900	S	ML, N
58	408	14							
59									
60	10,419	240	38	36	Cook sand	Pen	1,300	S	ML, N
61	2,707	25	36	34	Frye sand	Pen	450	S	ML, N
62	5,541	32	38	36	Hope sand	Pen	1,500	S	ML, N
63	1,945	21	40	38	Caddo	Pen	3,500	L	N
64	2,892	210	39	38	Bluff Creek	Pen	1,600	S	N
65	1,209	43	38	36	Tannehill	Pen	1,100	S	ML, N
66	1,384	13	40	38	Bluff Creek	Pen	1,650	S	ML, N

[b] Footnotes to column heads and explanation of symbols are given on page 240.

had Swastika sand from 2915 to 2926 ft. and was good for 450 bbl. per day. Later in the year the Texas No. 6 Carter in sec. 13, block 19, T. & P. R. R. Co. survey, Jones County, 2 miles west of the Humble-Horton well, discovered the Swastika sand from 3132 to 3154 ft. and was good for 100 bbl. per day.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres	Total Oil Production, Bbl.	
			Oil	To End of 1938	During 1938
67	Simmons-Harvey, *Shackelford*	13	160	334,778	38,558
68	Tannehill-Matthews, *Shackelford*	11	300	2,228,449	100,420
69	Ivy, *Shackelford*	1	400	147,676	147,676
70	Other Fields, *Shackelford*			10,256,688	581,995
71	Total Shackelford County		5,575	35,750,717	2,104,190
72	Curry, *Stephens*	18	2,580	9,420,869	95,672
73	Strawn, *Stephens*	21	850	4,511,557	89,911
74	Other fields, *Stephens*		44,570	111,146,287	1,173,292
75	Total Stephens County			125,078,713	1,358,875
76	Carlisle, *Stonewall*	1	40	12,582	12,582
77	Miscellaneous, *Taylor*		170	269,507	28,833
78	Woodson, (Shallow), *Throckmorton*	13	120	709,385	13,620
79	Woodson, (Deep), *Throckmorton*	14	260	1,788,529	44,993
80	Others, *Throckmorton*		720	689,997	58,439
81	Total Throckmorton County		1,100	3,187,911	117,052

Line Number	Average Oil Production per Acre	Number of Oil and/or Gas Wells at End of 1938	Character of Oil, Approx. Average during 1938		Producing Rock				
			Gravity A.P.I. at 60° F.				Depth, Average in Feet		
	To End of 1938	Producing Oil Only	Maximum	Minimum	Name	Age[f]	To Top of Productive Zone	Character[g]	Structure[i]
67	2,092	12	40	38	Bluff Creek	Pen	1,700	S	N
68	7,428	90	39	37	Tannehill	Pen	1,150	S	MLN
69		23	40	38	King Strawn-Canyon	Pen	1,900–3,200	S L	A
70		1,079							
71		1,788							
72	3,574	51	39	38	Caddo	Pen	3,100	L	A
73	5,308	84	39	37	Strawn	Pen	1,850	S	ML, N
74	2,493	541							
75		676							
76		1	40	38	Strawn-Canyon	Pen	5,300	L	N
77	1,585	14							
78	5,911	10	38	36	Strawn	Pen	2,350	S	ML
79	6,878	10	39	37	Caddo	Pen	3,900	L	A
80		132							
81		152							

Oil and Gas Development in the Texas Panhandle for the Year 1938

By Henry Rogatz*

(New York Meeting, February, 1939)

Oil.—During the year 1938, there were 434 oil wells drilled in the Texas Panhandle, increasing the daily initial production by 192,706 bbl. —that is, 229 fewer oil wells drilled than in the previous year, with a decrease in total daily initial production of 129,626 bbl. The total daily potential of the field on Dec. 1, 1938, as determined by the Texas Railroad Commission, was 1,250,645 bbl., an increase of 210,663 bbl. over the previous year. On Dec. 1, 1938, the daily allowable of 82,466 bbl. was assigned to the field to be produced from 3931 wells. The total amount of oil produced for the year was 23,227,170 bbl. The total proven productive area includes 148,298 acres. This is 30,248 acres more than for last year, and represents a more accurate calculation of the areas and not new discoveries.

Gas.—There were 103 gas wells drilled during 1938, having a combined open flow of 3,166,300,000 cu. ft.; that is, 65 less than the number of wells drilled in 1937, with a decrease in the open flow of 3,144,488 cu. ft. per day.

Pipe-line Gas.—The pipe-line companies withdrew 230,307,854,000 cu. ft. of gas (a daily average of 630,980,000 cu. ft.). The total withdrawals by pipe line decreased 5,624,481,000 ft. from that of 1937.

Natural Gasoline.—Throughout the greater part of the year, 46 gasoline-extraction plants processed 1,376,186,000 cu. ft. per day, a total of 502,308,010,000 cu. ft. for the year. This gas yielded about 275,875,000 gal. of natural gasoline. The total daily capacity of all the plants is 2,519,500,000 cu. ft. During the latter part of 1938, one of these plants was shut down, leaving 45 plants operating at the close of the year.

Carbon Black.—Thirty carbon-black plants operated during 1938, burning 266,881,000,000 cu. ft., or a daily amount of 731,180,000 cu. ft. This produced approximately 400,000,000 lb. of carbon black. During the year one plant was dismantled and two plants were shut down.

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Refineries.—The total runs to the eight operating refineries for the year 1938 were 13,382,127 bbl., or a daily average of 36,663 bbl.—a daily increase of 672 bbl. over 1937.

Storage.—The oil in storage decreased 1,695,008 bbl., that is, from

TABLE 1.—*Oil and Gas Production in Texas Panhandle*

Line Number	County	Age, Years to End of 1938	Area Proved, Areas		Total Oil Production, Bbl.		Total Gas, Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells			Oil Production Methods at End of 1938		Pressure, Lb. per Sq. In.[d]		
									Completed to End of 1938	During 1938	At End of 1938	Number of Wells			Average at End of	
			Oil[1]	Gas	To End of 1938[2]	During 1938	To End of 1938	During 1938		Completed	Producing Gas Only	Flowing	Artificial Lift	Initial	1937 (July)	1938 (July)
1	Carson.....	17	19,570	220,383	29,935,263	2,343,420			781	76		y	y	430	335.8	337.9
2	Gray......	13	58,845	119,815	148,165,348	10,976,850			2,258	158		y	y	430	322.8	294.1
3	Hartley....	10	0	39,380	0	0			4	0		y	y	430	426.8	424.8
4	Hutchinson.	16	60,993	171,244	128,508,601	7,225,170			2,276	242		y	y	430	306.3	291.3
5	Moore.....	12	640	404,736	4,275,759	431,730			340	34		y	y	430	394.8	388.8
6	Potter.....	19	0	110,349	33,822	0			51	2		y	y	430	406.1	406.0
7	Wheeler....	13	8,250	121,299	14,704,584	2,250,000			725	24		y	y	430	282.5	268.6
	Total....		148,298	1,187,206	325,623,377	23,227,170	7,445,544	614,462	6,435	536	1,532			Av	350.6	345.6

[d] Footnotes to column heads and explanation of symbols are given on page 240.

[1] Figures for 1937 included only commercial producing oil acreages (over 4000 bbl. per acre recovery). The figures for 1938 include oil-producing acreage and proven commercial nonproducing acreage. This accounts for the increase in the figures for 1938 over those for 1937.

[2] The production figures for the early life of the field were poorly kept, if at all: therefore, these early years consist of estimate. The figures in this table include these estimates and are higher than those in the paper on the "Crude Oil Reserves of the Texas Panhandle" by Henry Rogatz, *Oil Weekly*, vol. 92, No. 5, page 40. In the latter article, the figures are actual pipe-line production records from each individual lease, and do not include some very early production figures.

7,296,008 bbl. to 5,601,000 bbl. The total storage capacity at the end of the year was 16,816,500 barrels.

New Developments.—For the first time, no new oil-producing areas were opened up, and no additional proven acreage was added to that of the previous year.

Wildcats.—Fourteen wildcat tests were completed, none of which discovered oil. One test (ITIO Davis, in southwest Sherman County) was completed for a 35 million cu. ft. gas well, which stopped in the upper Pennsylvanian (Cisco). The remaining wells were distributed

among the following counties: Armstrong, 1; Bailey, 1; Childress, 2; Collingsworth, 1; Cottle, 1; Dallam, 1; Hall, 1; Hansford, 1; Lamb, 2; Ochiltree, 1; Parmer, 1; Roberts, 1; Sherman, 1. All of these tests were dry.

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1938 — Gravity A.P.I. at 60° F. — Weighted Average	Producing Formation — Name	Age[e]	Depth, Average in Feet — Bottoms of Productive Wells	Depth, Average in Feet — To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938 — Name	Depth of Hole, Ft.
1	39	Big Lime series (Wichita-Albany) Granite Wash (Cisco?)	Per-Pen Pen	3,150	3,050	D, Da, La GW	x	x	AF	Granite Wash (E zone)	y
2	39	Big Lime series (Wichita-Albany) Granite Wash (Cisco?)	Pen Pen	3,100	3,000	D, D La GW	x	x	AF	Granite Wash E zone)	y
3		Big Lime series (Wichita-Albany) Granite Wash (Cisco?)	Pen	3,200	2,900	GW	x	x	AF	Granite Wash (E zone)	y
4	35	Big Lime series (Wichita-Albany) Granite Wash (Cisco?)	Pen	3,000	2,900	GW	x	x	AF	Arbuckle (Ord)	5,333
5	31	Lower Big Lime series Wichita-Albany (Cisco?)	Per-Pen	3,500	3,400	L	x	x	AF	Arbuckle (Ord)	8,013
6	y	Big Lime series (Wichita-Albany) Granite Wash (Cisco?)	Per-Pen	2,500	2,300	D GW	x	x	AF	Granite Wash (E zone)	y
7	37	Big Lime series (Wichita-Albany) Granite Wash (Cisco?)	Per-Pen	2,550	2,450	D GW	x	x	AF	Arbuckle (Ord)	2,957

Development along the Fault Zone of South Central Texas in 1938

By Joseph M. Dawson*

(New York Meeting, February, 1939)

Although eight new fields were discovered along the south central fault-line district of Texas during 1938, only one can be considered as of major importance, and as a whole the year was one of no very great development. Several prospects, particularly two, were condemned through drilling, which had been considered important for probable Edwards limestone production. The oil produced was approximately the same as during 1937; namely, about 9 million barrels. This, of course, does not represent potential production but that allowed under proration. The year witnessed the very rapid decline of operations and interest in Austin chalk production. It has been found that only in rare instances will chalk production pay for itself, because the wells decline extremely rapidly and the recovery per acre, formerly estimated at 2500 bbl., is now considered to be around 1000 barrels.

Table 1.—*Discoveries in South Central Texas in* 1938

Field	Depth, Ft.	Formation	Production in 1938, Bbl.	Discovery Date
Chriesman-Burleson	7,182	Edwards	11,000	5-25-38
Dunlay-Medina	716	Serpentine	1,933	4-15-38
Frio Town-Frio	2,680	Austin chalk	1,000 (est.)	3- 7-38
LaCoste-Bexar	1,196	Anacacho lime	1,211	3- 4-38
Riddle-Bastrop	1,773	Austin chalk	13,658	6-24-38
Shattel-Frio	4,800	Austin chalk	703	10-20-38
Sisterdale-Kendall	1,002	Ordovician lime	364	10- 7-38
Walnut Creek-Caldwell	1,335	Serpentine	5,611	6-24-38

There was an intent interest in the drilling and producing of edge and abandoned properties in the three Edwards lime producing fields; namely, Luling, Salt Flat and Darst Creek. Many good wells were completed on properties formerly considered below the water level or produced beyond the economic limit. The Edwards is penetrated only a few inches and a very small charge of acid is used. The results have been surprisingly

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good, even where leases appear to have been produced to the extreme commercial limit. There were 494 wells drilled as compared with 567 in 1937. Of this number, 238 produced oil, 5 gas, and 251 were failures. Only 16 wells were drilled by so-called major companies, the remaining operations being by independents.

TABLE 2.—*Summary of Production*

Field	Production for 1938	Field	Production for 1938
Somerset-Atascosa	213,538	Bruner (Salt Flat)-Caldwell	1,415,933
Bateman-Bastrop	41,013	Walnut Creek-Caldwell	5,611
Carroll-Bastrop	11,593	Pearsall-Frio	195,024
Cedar Creek-Bastrop	20,354	Shattel-Frio	703
Hilbig-Bastrop	118,553	Darst Creek-Guadalupe	2,674,956
NE. Cedar Creek-Bastrop	317	Darst Creek Extension-	
Riddle-Bastrop	13,658	Guadalupe	49,516
Yost-Bastrop	13,860	Manford-Guadalupe	7,908
Alta Vista-Bexar	3,141	Nash Creek-Guadalupe	28,147
Dobrowoski-Bexar	48,776	Zoboroski-Guadalupe	36,431
Gas Ridge-Bexar	2,719	Sisterdale-Kendall	364
LaCoste-Bexar	1,366	Chicon Lake-Medina	9,132
Lone Oak-Bexar	873	Dunlay-Medina	1,933
Von Ormy-Bexar	51,131	Hondo-Medina	2,378
Yturri-Southton-Bexar	18,340	Ina-Medina	2,??2,455
Branyon-Caldwell	726,686	Minerva-Milam	72,876
Buchanan-Caldwell	71,200	Kimbro-Travis	365
Burdett Wells-Caldwell	34,685	Manda-Travis	2,564
Dale-Caldwell	79,001	Byersville Plug-Williamson	35,573
Dunlap-Caldwell	25,450	Chapman-Williamson	82,530
Larremore-Caldwell	23,206	Thrall-Williamson	13,173
Luling-Caldwell	2,546,437	Batesville-Zavala	465
Lytton Springs-Caldwell	117,455	Grand Total	8,821,411

Two prospects condemned by drilling were the Paige block, largely held by the Humble Oil & Refining Co. in eastern Bastrop County, and the Shattel block in Frio County, also largely controlled by the Humble. Each prospect had had a very considerable amount of exploratory work and the structure had been definitely worked out. The Paige block reached the Edwards below 7000 ft. on a fault structure carrying sulphur water. Five wells were drilled on the Shattel block, northeast of Pearsall, Frio County, two of which showed oil. One was produced for a time from the Austin chalk but was abandoned. A deep failure of importance was drilled west of Carrizo Springs, Dimmit County, on what is known as the Carrizo Springs arch, where the Edwards was reached at around 7100 ft. Amon G. Carter drilled a deep Ordovician failure on a well-recognized structure in central Edwards County, near Rock Springs.

Five failures were drilled in Maverick County, principally on the extremely large well-recognized Chittim arch.

Of the eight fields found, only Chriesman, in western Burleson County, can be classed as important. The Red Bank Oil Co. completed its No. 1 Coffield as a pumper from the Edwards limestone at a total depth of 6182 ft. with a settled production of around 75 bbl. per day. Two failures had previously been drilled. The discovery produced approximately 11,000 bbl. in 1938, and the production appears to be settled. No additional tests have been drilled, although development will be required in 1939. This well is on a major faulted structure and may develop into a major field.

Of the seven remaining so-called discoveries, two were from serpentine, four from the Austin chalk, and one from Ordovician limestone (Table 1).

Approximately 600,000 acres of land were taken under lease as compared with 900,000 in 1937. Average cost per acre was $1.00. Most of the leasing took place in the large and relatively unexplored counties southwest of San Antonio; namely, Frio, LaSalle, Dimmit, Zavala and Maverick. Geophysical operations of all kinds increased considerably. A summation of the production by fields for 1938 is given in Table 2.

Oil and Gas Development in South Texas during 1938

By Michel T. Halbouty,* Member A.I.M.E.

(New York Meeting, February, 1939)

The area for which oil and gas development is reported for 1938 in this paper is larger than that covered by the report for 1937, in that besides Duval, Jim Hogg, McMullen, Starr, Webb and Zapata Counties, comprising the Laredo district, this paper also includes the South Corpus Christi district, which is composed of the following counties: San Patricio, Nueces, Jim Wells, Kleberg, Kenedy, Brooks, Willacy, Hidalgo and Cameron, all heretofore included in A.I.M.E. Gulf Coast reports. In the map, Fig. 1, the area known as South Texas is represented by the counties south of the heavy black line.

Production in the South Corpus Christi district, which covers an area that extends inland for 50 miles and follows the coast line, is primarily in zones ranging from the Catahoula, through the Frio sands, into the Vicksburg horizon. General exploration is done mainly with geophysics because in this district production is directly dependent upon structural conditions.

In the Laredo district most of the production is from sand lenses; therefore, because these shallow sand lenses represent old shore lines which are monoclinic in character, the most satisfactory method of exploration in the Laredo district is drilling. This type of production centers around Duval County and follows a northeast-southwest trend along the Mirando district.

Although drilling operations showed a decline from the preceding year, 1938 was highly successful as far as new discoveries and developments were concerned, and results of the year's operations should have an important effect on the near future trend of exploration and drilling. Besides the discovery of several new fields and many new sands in established fields, 1938 saw the discovery of a new Vicksburg sand trend and the first marine drilling off the South Texas Gulf Coast.

Many new fields were discovered during the year, but only a few were subjected to an extensive drilling program. Several already established fields, especially in the Laredo district, received a large amount of drilling as new sands and extensions enlarged the producing areas, a

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notable example being the Hoffman field in Duval County. Most active among the new fields were Alice, Jim Wells County; Turkey Creek (West Saxet), Nueces County; East White Point, San Patricio County;

FIG. 1.—LOCATION OF OIL AND GAS FIELDS IN SOUTH TEXAS (AREA SOUTH OF HEAVY BLACK LINE).

and Fitzsimmons and Casa Blanca, Duval County. Most of the activity in established fields was largely centered in Hoffman and Benavides, Duval County; Ezzell, McMullen and Live Oak Counties; Oilton, Webb

County; Samfordyce, Starr and Hidalgo Counties; Luby and Saxet in Nueces County; and Aransas (McCampbell) field in San Patricio and Aransas Counties. (See Table 4.)

There were 1141 oil wells, 76 gas wells and 218 dry holes completed in South Texas fields during the year. Of these, 682 oil wells, 44 gas wells and 143 dry tests were drilled in the Laredo district, exclusive of 21 oil wells and 5 dry holes completed in the Live Oak County portion of Ezzell field. Completions in the South Corpus Christi district, exclusive of 39 oil wells and 3 dry holes drilled in the Aransas County portion of the Aransas Pass (McCampbell) field, totaled 459 oil wells, 32 gas wells and 75 dry holes.

In a search for new producing areas, 275 *rank* wildcats were drilled, of which 17 discovered oil fields, 8 found distillate fields, 7 opened gas-producing areas, and 243 were abandoned as dry holes. Discoveries were: 13 oil fields, 3 distillate fields, 3 gas areas and 190 dry holes in the Laredo district; 4 oil fields, 4 distillate fields, 4 gas areas and 53 dry tests in the South Corpus Christi district. These figures show an average of one producer in 11 tests for the Laredo district and one producer in 5 tests for the South Corpus Christi district. (See Table 5.)

Developments during 1938 included the completion of the first well to produce below 9000 ft. in South Texas—the Atlantic Refining Company's discovery well at Weslaco, Hidalgo County, the American Rio Grande and Irrigation Co. No. 1, which was completed flowing gas and distillate on Jan. 18 from perforations at 8995 to 9005 ft. This well was later plugged back and recompleted at 8634 to 8642 ft., total depth being 9182 feet.

On Nov. 23, South Texas became holder of the deep-well record for Texas when the previous record of 12,786 ft. was passed by Union Producing Company's Minnie Brown No. 1, in the Agua Dulce field, Nueces County. Another record was set by this well when, on Dec. 21, it passed the record of 13,409 ft., made by Fohs Oil Company's State Bay Baptiste No. 1, Terrebonne Parish, Louisiana, previously the deepest well east of the Rocky Mountains. At the end of the year, Minnie Brown No. 1 was being plugged back after reaching 13,728 feet.

Marine (locations made either in bay or Gulf waters) drilling had its start during the year, an aftermath of three years of geophysical work that mapped structures lying in the bays and lagoons near Corpus Christi and down the coast in the shallow and deep waters of this district. Although the few submerged wildcat operations during the year were not entirely successful in so far as obtaining production was concerned, the near future should see an increase in marine drilling as the technique of this type of drilling is improved and facilitated.

Vicksburg production, almost unknown in South Texas until recently, now appears to be favorably situated in a trend approximately 25 miles

wide and 200 miles long, reaching from the Mexican border lines of southeast Starr and most of Hidalgo Counties, thence in a north and northeast direction and parallel to the Gulf of Mexico into Jackson County. The first Vicksburg production in South Texas was discovered in September 1932 by Gulf Production Company's D. M. O'Connor No. 2 when it flowed several million cubic feet of gas per day at 5687 to 5710 ft., later being abandoned in heaving shale at 6860 feet. Since then little attention had been given to this formation, first because it was too deep to be drilled along the Frio trend and secondly because very few tests to the Jackson encountered the Vicksburg, which is a wedge between the Frio and Jackson formations. Impetus was given to the exploration of this trend through the discovery of East Premont, Jim Wells County, on Dec. 6, 1937, by Magnolia Petroleum Company's A. A. Seeligson No. 7, which flowed 1386 bbl. of 36.5° gravity crude per day through perforations at 6585 to 6595 ft. in a Vicksburg sand body at 6582 to 6694 ft. Flow was through 9/64-in. choke under pressures of 2000 lb. on tubing and 1800 lb. on casing, total depth of the well being 8165 ft. This field is expected to be one of the major producing areas of South Texas, although development to date has been rather slow. With the discovery in 1938 of the Alice field, also in Jim Wells County, the Vicksburg trend play was on. Because of the steep rate of dip in the formations toward the Gulf, estimated at about 200 ft. to the mile, the trend will probably be limited to a belt about 25 miles wide.

Interest along the Vicksburg trend has been centered on the Kelsey anticline, on which two producers, 12 miles apart, were completed. These wells, the Sun Oil Company's Mrs. A. McKinney No. 1, and the Humble Oil & Refining Company's Mrs. A. K. Bass No. 2, were the discovery wells for the Sun field in Starr County and Kelsey field in Jim Hogg County.

Producing Trends

The South Texas area covered in this report contains six producing trends whose productive zones range from the Miocene to the Mount Selman Eocene in age, as follows: Marginulina area, Frio trend, and Vicksburg trend, all in the South Corpus Christi district, and the Benavides trend, shallow Mirando trend and Mount Selman trend, all in the Laredo district. These trends extend inland from the coast in the order named and all tend to follow a northeast-southwest direction parallel to the coast lines of South Texas (Fig. 1).

The production of oil in the Laredo area during the year totaled 29,846,600 bbl., an increase of 313,320 bbl. over 1937. Production for the Corpus Christi area totaled 26,305,522 bbl. for 1938, an increase of 1,231,249 bbl. over 1937. The production for both districts totaled 56,152,122 bbl. for 1938, an increase of 1,544,569 bbl. over 1937.

Marginulina Area.—The *Marginulina* formation, which lies along the outer rim of the Gulf Coast and extends along most of the South Texas coast, is developed far below the surface as a wedge between the *Heterostegina* and Frio zones, and since it extends downdip toward the sea, it does not outcrop at the surface. Production from the *Marginulina* zone has been found in several coast fields, among them the Flour Bluff field, Nueces County, where it produces at depths of 6500 to 6700 ft. The Frio also produces along this trend at depths below 7000 ft. As possibilities of this area may extend down to the Vicksburg and even lower levels, and with marine drilling coming into its own, and all submerged tests meaning a test of the *Marginulina*, this trend should see an increasing amount of exploration with a resulting increase in producing areas.

Frio Trend.—The first discovery along the Frio trend was in the Refugio field of Refugio County. Since then continued exploration has carried this trend down the coast into San Patricio, Nueces, and other counties farther south. Production is obtained above 4000 ft. in the Catahoula, between 4000 and 5000 ft. in the *Heterostegina*, or Greta sand, and below 5000 ft., to depths of more than 9000 ft., in the Frio zone. The Catahoula and *Heterostegina* zones produce lower-gravity crudes than does the Frio, which produces light oils and distillates, and so far, the Frio trend has been the most prolific of all South Texas producing areas.

Vicksburg Trend.—The newest trend developed in this district is the Vicksburg. Like the *Marginulina*, this is a wedge formation, but differs in that its shore line is found at a much shallower level and extends inland much farther. The Vicksburg shore line is found at an average depth of 2500 ft. where it wedges between the Frio and Jackson. Continuing inland updip, the Vicksburg is absent, the Frio becoming adjacent to the Jackson, as in the Laredo district. Production controlled by the Vicksburg shore line is expected to be found as far seaward and downdip from the contact point of the Frio and Jackson formations as the Vicksburg sands are thick enough to provide production. This main productive trend should continue downdip until the effect of the shore line is lost because of the steep dip of the formation; at this point, where the formations are probably to be found below 7500 ft. and continuing in depth seaward, production from the Vicksburg will depend on good structural conditions. The Vicksburg zone, because of its dip, will in all probability be one of thick sand bodies from which yields will be great when productive. It can readily be seen, therefore, that when an area is sufficiently close to the Vicksburg shore line to be affected by its oil-bearing qualifications, and at the same time be supplied with a good structural trap, the resulting field, sand lenses against regional structural features, will probably be of major proportions. Alice and

East Premont are examples of this type of reservoir. It is estimated that at the South Texas Gulf Coast the Vicksburg will be topped at approximately 10,500 to 11,000 feet.

Benavides Trend.—The Benavides trend centering around eastern Duval County was first brought to light in 1937, with the discovery of Sweden and Benavides (North Sweden). However, a little shallow production has been obtained for many years from several known salt domes in that area. The Benavides field, largest in this area, produces

Field Discoveries in 1938 *with the Trend in Which Each Is Located*

Field	County	Trend	Type of Production to Date
Agua Dulce (North)......	Nueces	Frio	Distillate
Alice....................	Jim Wells	Vicksburg	Oil
Alfred...................	Jim Wells	Vicksburg (Frio sand)	Oil
Bandera..................	Jim Wells	Vicksburg (Jackson sand)	Gas
Barbacoas (North)........	Starr	Mirando	Oil
Bird Island..............	Kleburg (Submerged)	Marginulina (Frio sand)	Gas
Campana..................	McMullen	Mirando	Oil
Casa Blanca..............	Duval	Mirando	Oil
Cedro Hill...............	Duval	Mirando	Oil
Fitzsimmons..............	Duval	Benavides	Oil
Houser...................	Webb	Mirando	Distillate
Kelsey...................	Jim Hogg	Vicksburg	Oil
Killam (North)...........	Webb	Mirando	Oil
La Reforma...............	Starr	Vicksburg (Frio sand)	Distillate
Loma Valdez..............	Webb	Mirando	Gas
Longhorn.................	Duval	Benavides	Oil
Los Picachos.............	Duval	Mirando	Oil
Munson...................	McMullen	Mirando	Oil
McAllen..................	Hidalgo	Vicksburg	Distillate
Plymouth (East)..........	San Patricio	Frio (Heterostegina sand)	Gas
Rincon...................	Starr	Vicksburg	Distillate
Riverside................	Nueces	Frio	Gas
Sacatosa.................	Starr	Mirando	Gas
San Salvador.............	Hidalgo	Vicksburg (Frio sand)	Distillate
San Jose.................	McMullen	Mirando	Oil
Sun (McKinney)...........	Starr	Vicksburg	Oil
Tesoro...................	Duval	Benavides (Pettus sand)	Oil
Turkey Creek.............	Nueces	Frio	Oil
White Point (East).......	San Patricio	Frio	Oil
Weslaco..................	Hidalgo	Vicksburg (Frio sand)	Distillate
Young (Charco Blanco)...	Starr	Mirando	Gas

from 3800 to 5400 ft., from the top of the Jackson into the Cockfield. This trend has shown great possibilities, and production is based on the idea expressed above in regard to the Vicksburg; that is, that sand lenses, when downdip from the shore line and found on a structural trap, will provide favorable possibilities.

Shallow Mirando Sand Trend.—The shallow Mirando sand trend produces principally from the Jackson, and at some places from the Frio, Cockfield and Yegua at depths ranging from 150 to 3000 ft. Production is obtained mostly from sand lenses on old shore lines. Recent developments in the Cockfield, Yegua and lower sands point to good possibilities for these lower zones. However, as far as these deeper horizons are concerned, it is likely that fields of minor or no structural relief, such as the Jackson shore-line fields, will not be desirable places in which to drill. However, areas of sufficient structural features should attract deeper exploration to these interesting sands.

Mount Selman Trend.—The Mount Selman trend, rather disappointing to date, runs through western Webb and Zapata Counties. A little high-pressure gas with distillate has been found at shallow depths, but, so far, exploration has been rather meager. The Lopena gas field of Zapata County, which produces gas from the Queen City (Mt. Selman) sand at 2150 ft., is a good example of this type of production.

LAREDO DISTRICT

Duval County

Los Picachos Field.—On April 13, V. G. Schimmel et al.'s E. R. Hagist No. 5 was completed as a pumper producing 28 bbl. of 23° gravity oil, 40 per cent salt water, daily, from the Government Wells zone at 2166 to 2196 ft., to discover the Los Picachos field, 1½ miles west of the Seven Sisters field in northern Duval County. This well topped Cole sand at 1536 ft. and found the Government Wells zone at 2166 ft. Sandy shale, sand and shells with oil and gas show, was cored from 2166 to 2190 ft., saturated oil sand to 2193 ft. and oil sand with salt water to 2196 ft. Casing was set at 2176 ft. This area is on the upthrow side of a fault running in a northeast-southwest direction and between it and the Seven Sisters field.

Fitzsimmons Field.—On May 26, the Fitzsimmons field, northeastern Duval County, was opened through the completion of H. J. Porter et al.'s D. Fitzsimmons No. 1, which flowed 108 bbl. of 47.1° gravity oil per day through 9⁄64-in. choke under pressure of 370 lb. on tubing and 1020 lb. on casing. The test cored broken Pettus sand and sandy shale with oil and gas odor at 4270 to 4295 ft. and oil sand from 4295 to 4303 ft. The top of the Pettus zone was found at 4261 ft. and total sand section, after discounting shale present, was approximately 20 ft. This area,

on trend with the Benavides field, is $\frac{3}{4}$ mile northwest of two dry holes previously drilled to the Pettus. This structure is considered to be a monocline dipping to the southeast.

SECOND SAND.—A second sand for the Fitzsimmons field was opened by H. J. Porter's No. 2-A Fitzsimmons, offset to the discovery, when it flowed 55 bbl. of oil per day from *Hockelyensis* sand at 3592 to 3607 ft. Flow was through $\frac{1}{4}$-in. choke, under 1200 lb. tubing pressure and 1325 lb. casing pressure, from perforations in the lower portion of the sand.

Casa Blanca Field.—Magnolia Petroleum Co. completed its Duval County Ranch Co. No. 1 as an oil well pumping 37 bbl. of 20° gravity crude on a 12-hr. gauge, to discover, on May 31, the shallow Casa Blanca pool, 2 miles southeast of Charamousca and 7 miles northwest of Freer. Production was from Cole sand, containing gas odor at 1180 to 1186 ft., and oil from 1186 to 1190 ft. This field is considered to consist of sand lenses on a minor monocline.

Tesoro Field.—The Tesoro field, Duval County, 5 miles southwest of Alice, was discovered on June 20 by Arkansas Fuel Company's Cuellar Brothers No. 1, which, on a 20-hr. gauge, flowed 78.5 bbl. of 45° gravity oil, 5 per cent salt water, from perforations at 5109 to 5117 ft., in Pettus sand found at 5108 to 5136 ft.; the lower portion of this sand showed salt water. Flow was through $\frac{3}{8}$-in. choke under 150 lb. tubing pressure and 670 lb. casing pressure. A Yegua sand at 5406 to 5412 ft. showed oil but developed salt water on a test. Production is thought to be controlled by lenses on a structure showing nosing and faulting.

Cedro Hill Field.—The Cedro Hill field was opened on Nov. 28 by Magnolia Petroleum Company's D.C.R.C. No. 2, sec. 189, which was completed as a pumper producing 50 bbl. of 20° gravity crude daily from Cole sand at 1445 to 1451 ft. This field, 3 miles west of the Sarnosa field and 2 miles south of the Colmena field, apparently is on a sand lense of the usual Mirando trend type.

Longhorn Field.—Longhorn Drilling Company's M. M. Miller No. 1, sec. 28, about $1\frac{1}{2}$ miles southwest of the South Sweden field, was completed in December flowing 203 bbl. of 45° gravity oil daily through $\frac{5}{32}$-in. choke under 780 lb. tubing pressure and 1000 lb. casing pressure to discover the Longhorn field. Production was obtained from Government Wells (Gravis) sand, cored at 4893 to 4899 feet. This is considered a new field rather than an extension. Geophysics indicated a large structure.

New Sands in Existing Fields

Benavides Field.—SIXTH SAND.—Just northeast of the Benavides field production, F. J. Gravis' A. I. Vaello flowed several million cubic feet of gas and sprayed a little distillate through perforations in the Cole zone at 3965 to 3972 ft., to open another sand level in this formation

in January. Flow was through ¼-in. choke and under 1600 lb. working pressure.

Seventh Sand.—In January, Hiawatha Oil Company's Southland Life No. 6, after finding shale or sandy shale in the majority of the upper zones, salt water in sand at 4821 to 4825 ft., and a minor gas blow in the regular Pettus zone at 5390 to 5420 ft., drilled ahead to find a cap at 5495 to 5496 ft. and sand with a few shale streaks at 5496 to 5513 ft. The well was completed in this zone, which compares with the productive 5900-ft. sand in the Sweden (South) field, for a production of 300 bbl. of oil daily. A series of faulting accounts for the increased depth in the Sweden field.

Eighth Sand.—In March, Circle Oil Co. completed its Merle West No. 2, flowing 233 bbl. of oil through 9/64-in. choke on a 21-hr. gauge, as the first well brought in from the 4500-ft. horizon; flow was under 925 lb. tubing pressure and 1525 lb. casing pressure. This sand, found in this well at 4537 to 4552 ft., had previously been logged by a number of wells drilled in the field, but all were carried ahead to the regular sands below 4700 ft. for completion.

Charamousca Field.—A new sand for the Charamousca field was opened by N. V. Duncan's Warden and Drought No. 20, which was completed pumping 65 bbl. of oil per day from *Upper Hockleyensis* sand at 1094 to 1101 ft. The regular Mirando sand is found several hundred feet deeper.

Sweden Field.—A new sand for the Sweden field was opened during the latter part of the year by Hiawatha Oil and Gas Company's Miller No. 5, 4700 ft. west of production. It found sand and shaly sand at 4895 to 4915 ft. and on completion flowed 50 bbl. of oil per day through ¼-in. choke under no tubing pressure and 120 lb. casing pressure. This sand is in the Chernosky zone.

Extensions to Established Areas

Eagle Hill Field.—V. G. Schimmel gave the Eagle Hill field a ½ mile extension in the completion of No. 1 Foster, for a production of 107 bbl. of oil per day on pump. This well, in sec. 206, found Cole sand at 1517 to 1527 ft., shale at 1527 to 1534 ft. and oil sand at 1534 to 1539 ft., total depth.

Rancho Solo Field.—The Rancho Solo field was extended ¾ mile east by Stewart and Nye's W. R. Peters No. 1, sec. 29, which produced 105 bbl. of oil daily from perforations at 1853 to 1856 ft. in Cole sand at 1853 to 1870 ft. The well also showed for a 30,000,000 cu. ft. gasser at 2586 to 2620 ft. in Mirando sand. However, after drilling to 3200 ft., the test was plugged back to 1950 ft. and completed in the Cole zone.

Hoffman Field.—W. A. Wagner's No. 1 L. C. Lape, sec. 497, extended the Hoffman field a mile south, when it flowed 200 bbl. of oil daily from

TABLE 1.—*Oil and Gas Production in South Texas in* 1938

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.[1]		Number of Oil and/or Gas Wells					Oil-production Methods at End of 1938	
								During 1938		At End of 1938		Number of Wells	
			Oil	Gas[a]	To End of 1938	During 1938	Completed to End of 1938	Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Flowing	Pumping
1	Agua Dulce, *Nueces*	10	550	9,500	508,480	197,552	61*y*	8		1*y*	46*y*	1	0
2	North Agua Dulce, *Nueces*	¾	50	0	10,252	10,252	2	2	0	2			
3	Albercas, *Webb*	11¾	250	200	2,483,146	19,998	100	0	0	17	0	1	16
4	Alfred, *Jim Wells*	1	60	0	30,689	30,689	3	3	0	2	0	0	2
5	Alice, *Jim Wells*	¾	1,100	200	473,969	473,969	63	63	0	50	8	49	1
6	Alta Mesa, *Brooks*	12½	420	180	342,165	178,095	26	8	0	21	3	6	15
7	Alta Verde, *Brooks*	2¾	50	0	9,044	5,929	6	1	0	2	0	0	2
8	Alworth, *Jim Hogg*	12	80	570	27,793	0	16	1	1	0	0	0	0
9	Andrews, *Zapata*	14¾	0	2,000	Gas	Gas	12	1		0	4		
10	Angelita, *San Patricio*	4¾	40	0	31,707	783	2	0	0	1	0	0	1
11	Aransas (Gas), *San Patricio*	7¾	0	80	Gas	Gas	3	0	0	0	2		
12	Aransas Pass (McCampbell), *San Patricio and Aransas*	2½	1,500	20	2,818,981	1,877,121	150	52	0	139	2	138	1
13	Armagosa, *Jim Wells*	7¾	0	400	Gas	Gas	6	1	0	0	4		
14	Aviator, *Webb*	16⅔	955	320	5,773,820	116,675	216	0	2	75	0	0	75
15	Baldwin, *Nueces*	3½	270	0	567,724	107,969	9	0	0	8	1	0	8
16	Barbacoas, *Starr*	5⅔	80	580	31,466	3,662	13	0	1	2	0	1	1
17	North Barbacoas, *Starr*	⅔	20	0	Included in	Barbacoas	2	2	0	0	0	0	0
18	Benavides, *Duval*	1¾	5,900	200	4,289,234	3,677,100	252	128	0	237	11*y*	226	11
19	Bird Island, *Kleburg*	0	0	20	Gas	Gas	1	1	0	0	0		
20	Blas Uribe, *Zapata*	5	0	80	Gas		2	0	2	0	1		
21	Calliham, *McMullen*[2]	20	430	730	761,292	76,572	132	8	5	58	11	0	58
22	Campana, *McMullen*	¼	10	0	*y*	*y*	1	1	0	0	0	0	0
23	Captain Lucey, *Jim Wells*	6¾	120	200	405,239	107,450	17	0	0	6	11	4	2
24	Carolina Texas, *Webb*	17	110	1,460	257,111	2,184	64	0	0	1	14	0	1

[a] Footnotes to column heads and explanation of symbols are given on page 240.
[1] Where production figure is unobtainable production allowable is used.
[2] Includes South Calliham.

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d] Initial	Character of Oil, Approx. Average: Gravity A.P.I. at 60° F. Weighted Average	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
		Gas	Catahoula	Olig	2,005	1,998	SH		10			
	800	Gas and Distillate	Frio	Olig	4,675	4,666	SH		9			
1	1,650	59	Frio	Olig	4,850	4,800	SH	30	15	DF	Yegua	13,728
		39.8	Frio	Olig	5,307	5,295	Ss	—	12			
	2,500	55	Frio	Olig	6,845	5,700	SH		16			
2	1,820	Gas	Frio	Olig	4,834	4,810	SH	30	24	DF	Vicksburg	8,706
3	600	21	Cole	Eoc	2,175	2,125	Ss	Por	17	MF	Yegua	3,710
4	125	47	Frio	Olig	3,234	3,223	Ss	30–35	11	MF	Jackson	5,509
	1,350		Frio	Olig	3,533	3,480	Ss	28.7	16			
	750		Frio	Olig	4,799	4,788	Ss	Por	11			
	75		Frio	Olig	5,037	5,031	Ss	Por	6			
5	1,900	45	Frio	Olig	5,161	5,141	Ss	Por	20	A	Cockfield y	7,335
			Frio	Olig	5,223	5,211	Ss	Por	12			
	900		Vicksburg	Olig	5,452	5,375	Ss	Por	50			
6	500	Gas	Oakville	Mio	1,140	1,100	Ss	Por	20	D	Vicksburg	8,022
	175	25	Catahoula	Olig	3,585	2,450	Ss	Por	20			
7	100	26.2	Cap Rock	Mio	926	916	S	Por	10	DS	Yegua	5,096
8		21	Upper Jackson	Eoc	1,030	1,020	Ss	Por	6	ML	Jackson	2,199
9		Gas	McElroy	Eoc	1,515	1,510	Ss	Por	5	MF	Yegua	2,312
10	1,550	33.7	Frio	Olig	5,382	5,370	Ss	Por	10	Nf	Frio	7,131
11	1,480	Gas	Catahoula	Olig	3,663	3,653	Ss	Por	10	D	Frio	6,026
	2,250		Marginulina	Olig	6,554	6,539	Ss		15			
12	2,200	44	Frio	Olig	6,888	6,780	Ss	25–34	15	Nf	Frio	8,889
	2,700		Frio	Olig	7,143	7,085	Ss		15			
13		Gas	Discorbis-Het.	Olig	2,200	2,170	Ss	Por	10	D	Yegua	6,115
14		21	Mirando	Eoc	1,660	1,525	Ss	Por	11	MF	Cook Mt.	3,975
15		Gas	Oakville	Mio	3,250	3,230	Ss	Por	12	AF	Frio	6,610
	225	25.8	Catahoula	Olig	4,069	3,874	Ss	Por	12			
		Gas	Catahoula	Olig	715	685	Ss	Por	10			
16		24	Frio	Olig	2,712	2,450	Ss	Por	26	Df	Yegua	5,640
	2,200	58	Cockfield	Eoc	5,398	5,376	Ss	Por	22			
17		24	Frio	Olig	2,669	2,663	Ss	Por	6	Df	Frio	3,014
	400	43	Cole	Eoc	3,972	3,864	Ss	Por	22			
	925	43	Chernosky	Eoc	4,552	4,537	Ss	Por	15			
	460	43	Upper Govt. Wells	Eoc	4,755	4,730	Ss	Por	20			
18	750	43.6	Lower Govt. Wells	Eoc	4,830	4,755	Ss	Por	25	AF	Yegua	6,510
	400	44.7	Pettus	Eoc	5,352	5,330	Ss	Por	22			
	190	45	Cockfield	Eoc	5,518	5,496	Ss	Por	17			
19	2,700	Gas	Marg.-Frio	Olig	7,310	7,200	Ss	Por	80	AF	Frio	9,636
20		Gas	Jackson	Eoc	1,840	1,825	Ss	Por	15	ML	Yegua	3,000
		20	Cole-Hock[9]	Eoc	876	780	Ss	Por	28			
21		20.6	Govt. Wells—Pettus[9]	Eoc	1,060	1,030	Ss	Por	10	MF	Carrizo	5,301
		Gas	Loma Novia	Eoc	1,236	1,230	Ss	Por	6			
22		22	Upper Govt. Wells	Eoc	2,517	2,492	Ss	Por	20	MF	Govt. Wells	2,519
	1,100	Gas	Disc.-Het.	Olig	4,000	3,893	Ss	Por	6			
23	200	39.6	Frio	Olig	5,370	5,350	Ss	Por	20	MF	Vicksburg	6,500
	725	42	Vicksburg	Olig	5,685	5,679	Ss	Por	7			
		Gas	Cole	Eoc	1,280	1,270	Ss	Por	10			
		Gas	McElroy	Eoc	2,200	1,800	Ss	Por	65			
24		34	Cockfield	Eoc	2,615	2,597	Ss	Por	10	DF	Mt. Selman	5,057
		46	Upper Saline Bayou	Eoc	3,198	2,947	Ss	Por	50			
		42	Queen City	Eoc	5,056	4,996	Ss	Por	60			

[9] In Calliham.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres: Oil	Area Proved, Acres: Gas[a]	Total Oil Production, Bbl.[1]: To End of 1938	Total Oil Production, Bbl.[1]: During 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Producing Oil[b]	At End of 1938: Producing Gas[c]	Oil-production Methods at End of 1938, Number of Wells: Flowing	Pumping
25	Casa Blanca, *Duval*	⅔	250	50	76,373	76,373	29	29		22	*y*	5	17
26	Cedro Hill, *Duval*	0	10	0	*y*	*y*	1	1	0	1	0	0	1
27	Chapman, *Nueces*	1¾	50	0	41,410	13,098	2	0	0	1	0	1	0
28	Charamousca, *Duval*[3]	3¼	210	0	189,493	96,268	21	4	0	19	0	0	19
29	Charco Redondo, *Zapata*	25	570	60	183,700	2,748	165	0	0	47	0	0	47
30	Clara Driscoll, *Nueces*	3	500	200	972,399	504,563	49	24	0	41	3	16	25
31	South Clara Driscoll, *Nueces*	1⅔	300	20	162,105	144,891	14	12	0	12	0	10	2
32	Clopton-Green, *Starr*	1⅔	0	10	Gas		1	0	1	0	0		
33	Cole Group, *Duval-Webb* Gas	14½	65	7,035	615,824	Gas	110*y*	0		0	38*y*		
34	O'Hern	12	2,300	2,200	6,632,764	2,738,383	268*y*	6		229	2*y*	85	144
35	West	11¾	420	1,000	3,475,143	165,173	114*y*	0		56	*y*	0	56
36	Middle	3	20	160	18,150	7,300	2	0	0	1	1	0	1
37	Bruni[4]	4½	880	80	2,482,428	341,006	62*y*	6		41	*y*	18	23
38	Colmena, *Duval*	4	240	400	247,808	105,732	36	2	0	25	9	3	22
39	Colorado, *Jim Hogg*	2⅓	50	0	77,414	58,079	4	3	0	4	0	1	3
40	Comitas, *Zapata*	4⅓	725	40	1,048,304	209,971	176	12	10*y*	153	1	0	153
41	Conoco Driscoll, *Duval*	14	420	980	1,442,523	495,628	51	10	0	27	4	20	7
42	Corpus Christi, *Nueces*	3	1,500	0	6,050,114	1,123,999	251	4	*y*	130	5	115	15
43	Crowther, *McMullen*	19	80	0	25,000	0	23	0	0	0	0	0	0
44	Cuellar, *Zapata*	12	340	220	2,529,929	41,975	86	0	0	24	3	0	24
45	Eagle Hill, *Duval*	5¼	520	180	778,619	126,368	54	31		44	0	10	34
46	Edinburg, *Hidalgo*	4	100	0	500	0*y*	1*y*	0	0	1*y*	0	0	0
47	El Mesquite, *Duval*	3½	10	0	976	0	1	0	0	0	0	0	0
48	El Tanque, *Starr*	1⅔	280	30	163,182	92,213	15	4	0	12	1	7	5
49	Escobas, *Zapata*	9⅔	3,330	340	7,548,428	690,500	442	28	*y*	296	0	0	296
50	Ezzell, *McMullen, Live Oak*	1½	1,900	100	706,085	623,010	101	46	1	94	5	5	89
51	Fitzsimmons, *Duval*	⅔	390	0	199,999	199,999	39	39	0	38	0	38	0
52	Flour Bluff, *Nueces*	2½	2,580	20	3,451,820	1,735,930	113	14	0	110	1	105	5
	Government Wells, *Duval*[5]												
53	North	10⅓	4,750	250	{ 38,356,888	{ 4,296,399	{ 825	6	0	{ 462	5	0	462
54	South	8	2,750	350						266	7	6	260
55	Guerra (Cuevitas), *Starr*	5½	400	400	799,045	229,969	20	0	0	13	1	9	4
56	Hayden, *Starr*	2	0	20	Gas		1	0	0	0	0	0	0
57	Henne-Winch-Farris, *Jim Hogg*	14½	720	440	3,209,049	2,759	181	0	0	1	0	0	1

[3] Includes S.R.C.
[4] Includes East Bruni.
[5] Includes Ignacio.

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d] Initial	Character of Oil, Approx. Average: Gravity A.P.I. at 60° F. Weighted Average	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
25		20	Cole	Eoc	1,190	1,180	Ss	Por	10	ML	Jackson	2,021
26		20	Cole	Eoc	1,451	1,445	Ss	Por	6	ML	Cole	1,451
27	550	40.8	Catahoula	Olig	5,058	5,046	Ss	Por	12	ML	Frio	7,012
	625	41.8	Frio	Olig	6,484	6,464	Ss	Por	20			
28		20	Upper Hock.	Eoc	1,101	1,094	Ss	Por	7	MF	Cook Mt.	3,892
	75	20.5	Mirando	Eoc	1,550	1,525	Ss	Por	10			
29		17	Frio	Olig	200	150	Ss	Por	8	ML	Yegua	3,000
		Gas	Jackson	Eoc	995	989	Ss	Por	5			
30	750	25.8	Catahoula	Olig	3,908	3,807	S	Por	10	Df	Frio	7,308
	2,150	Distillate	Frio	Olig	5,433	5,333	Ss	Por	15			
31	1,000	23.6	Catahoula	Olig	3,930	3,917	Ss	Por	12½	D	Frio	5,689
		36	Frio	Olig	5,367	5,340	Ss	Por	16			
		42	Frio	Olig	5,460	5,450	Ss	Por	10			
32	425	Gas	Cole	Eoc	1,614	1,604	Ss	Por	10	x	Cook Mt.	4,620
33		Gas	Frio	Olig	515y	500	Ss	Por	10y	A	Reklaw	6,394
		Gas	Cole	Eoc	1,730	1,722	Ss	Por	8			
34		Gas	Mirando	Eoc	2,450	2,314	Ss	Por	10	A	Queen City	5,057
		28.5	Caddell-Cockfield	Eoc	2,945	2,750	Ss	Por	15			
35		21.5	Mirando	Eoc	2,346	2,335	Ss	Por	11	A	Mt. Selman	5,225
		Gas	Cockfield	Eoc	2,925	2,900	Ss	Por	10			
36		36	Cockfield	Eoc	2,952	2,945	Ss	Por	7	A	Yegua	2,952
37	900	36	Yegua	Eoc	3,280	3,270	Ss	Por	10	A	Reklaw	6,394
		41.7	Yegua	Eoc	3,450	3,400	Ss	Por	14			
38	525	22	Cole	Eoc	1,553	1,486	Ss	Por	19	ML	Yegua	3,396
39	65	48.6	Cockfield	Eoc	3,017	3,006	Ss	Por	8	ML	Cockfield	3,202
40		22.5	McElroy	Eoc	1,000	815	Ss	Por	10	ML	Cook Mt.	3,502
41		22.5	Cole	Eoc	2,470	2,448	Ss	Por	20	A	Yegua	4,695
		22.5	Hockleyensis	Eoc	2,900	2,884	Ss	Por	6			
		33	Govt. Wells	Eoc	3,448	3,370	Ss	Por	10			
42	1,650	23.3	Catahoula	Olig	4,096	4,076	S	Por	8	A	Frio	7,531
	825	36.5	Heterostegina	Olig	5,167	5,157	Ss	Por	10			
43		18	Diboll	Eoc	520	500	Ss	Por	y	ML	x	x
44	385	Gas	McElroy	Eoc	1,116	1,100	Ss	Por	16	ML	Mt. Selman	4,532
		22.5	McElroy	Eoc	1,350	1,325	Ss	Por	10			
45		22.5	Cole	Eoc	1,539	1,450	Ss	Por	20	MF	Cockfield	2,752
		23	Govt. Wells	Eoc	2,150	2,120	Ss	Por	20			
46		y	Frio	Olig	6,770	6,685	SH	Por	20y	D	Frio	7,508
47		43	Cockfield	Eoc	2,862	2,850	Ss	Por	12	ML	Yegua	3,502
48	200	Gas	Catahoula	Olig	429	425	Ss	Por	4	ML	Frio	2,379
		31	Frio	Olig	1,775	1,739	Ss	Por	14			
		30	Frio	Olig	1,879	1,866	Ss	Por	6			
49		20	McElroy	Eoc	1,050	1,020	Ss	Por	6	MF	Cook Mt.	3,500
		21	McElroy	Eoc	1,302	1,137	Ss	Por	14			
		21	McElroy	Eoc	1,600	1,485	Ss	Por	7			
50	90	19.7	Loma Novia	Eoc	1,550	1,490	Ss	Por	11	ML	Yegua	3,108
51	1,200	46	Hockleyensis	Eoc	3,623	3,592	Ss	Por	15	ML	Yegua	5,230
	370	47.1	Pettus	Eoc	4,303	4,260	Ss	24–28	25			
52	1,420	43.4	Marginulina	Olig	6,666	6,590	Ss	Por	24	D	Frio	7,504
53	600	Gas	Cole	Eoc	1,575	1,550	Ss	Por	17	MF	Mt. Selman	5,858
54		22.5	Govt. Wells	Eoc	2,350	2,280	Ss	Por	19			
		26	Loma Novia	Eoc	2,450	2,380	Ss	Por	11			
55	400	32	Upper Mirando	Eoc	2,055	2,047	Ss	Por	8	MF	Yegua	3,600
		35.2	Lower Mirando	Eoc	2,232	2,209	Ss	Por	23			
56	550	Gas	Frio	Olig	1,318	1,305	Ss	Por	13	ML	Frio	1,444
57		21	Mirando	Eoc	2,100	1,944	Ss	Por	16	AF	Yegua	3,546

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres: Oil	Area Proved, Acres: Gas[a]	Total Oil Production, Bbl.[1]: To End of 1938	Total Oil Production, Bbl.[1]: During 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Producing Oil[b]	At End of 1938: Producing Gas[c]	Oil-production Methods at End of 1938, Number of Wells: Flowing	Pumping
58	Hoffman, *Duval*[6]	5¼	1,500	350	1,940,069	1,024,130	261	134	0	225	9	155	70
59	Houser, *Webb*	½	20	0	*y*	*y*	1	1	0	0	0	0	0
60	Jacob, *McMullen*[7]	12	1,230	80	1,220,278	178,432	117	2	10*y*	82	0	0	82
61	Jennings, *Zapata*	24¾	400	1,700	*y*	334,426	*y*	0	0	93	4	3	90
62	Kelsey, *Jim Hogg-Brooks*	¼	60	0	7,857	7,857	3	3	0	3	0	3	0
63	Killam, *Webb*	1¾	780	100	491,490	332,245	83	19	0	68	5	0	68
64	North Killam, *Webb*	0	20	0	930	930	1	1	0	1	0	0	1
65	Kingsville, *Kleburg*	18	240	675	702,204	16,675	20	0	0	7	3	1	6
66	Kohler, *Duval*[8]	12½	360	5,000	626,358	51,964	82	0	0	14	24	2	12
67	Labbe, *Duval*	4	200	500	166,232	94,114	29	2	0	15	8	6	9
68	La Blanca, *Hidalgo*	2¼	160	0	274,249	183,399	8	1	0	7	0		
69	La Reforma, *Starr*	½	50	0	5,315	5,315	2	2	0	2	0		
70	Las Animas, *Jim Hogg*	1	50	80	9,356	9,056	8	4	1	5	1	5	0
71	Las Vieja, *Willacy*	2¼	40	0	3,009	0	1	0	0	0	0	0	0
72	Laurel, *Webb*	6½	220	320	677,679	4,075	33	0	5	6	2	0	6
73	Lease holders, *Webb*	16¼	10	20	25,000	0	3	0	0	0	0	0	0
74	Loma Alta, *McMullen*	3⅔	20	0	95,506	30,873	4	2	0	3	0	0	3
75	Loma Novia, *Duval*	4	7,410	270	16,721,166	4,651,470	758	0	0	713	5	27	686
76	Loma Valdez, *Webb*	1	0	10	Gas	Gas	1	1	0	0	0		
77	Loma Vista, *Duval*	3	10	0	14,615	3,241	1	0	0	1	0	0	1
78	London, *Nueces*	2	80	0	46,797	17,168	4	0	0	2	0	1	1
79	Longhorn, *Duval*	0	20	0	.		1	1	0	1	0	1	0
80	Lopena, *Zapata*	4½	0	1,040	Gas	Gas	13	0	0	0	13		
81	Lopez, *Webb-Duval*	3½	3,450	240	6,698,436	2,191,798	369	0	0	343	2	107	236
82	Los Olmos, *Starr*	13½	175	175	560,488	37,133	89	0	3	71	1	0	71
83	Los Picachos, *Duval*	¾	20	0	576	576	1	1	0	0	0	0	0
84	Luby, *Nueces*	1½	2,060	0	1,620,268	1,540,664	103	84	0	100	0	100	0
85	Lundell, *Duval*	1½	300	40	168,538	141,302	41	28	0	35	1	32	3
86	Martinez, *Zapata*	9⅓	0	850	Gas	Gas	20	0	0	0	20		
87	Mathis, *San Patricio-Live Oak*	14	0	100	Gas		6	0	0	0	0		
88	McAllen, *Hidalgo*	⅓	40	0	*y*	*y*	2	2	0	2	0		
89	Mercedes, *Hidalgo*	3¾	100	0	134,352	29,117	7	3	0	5	0		
90	Mestinas, *Hidalgo*	3⅓	80	0	*y*	*y*	1	0	0	0	0		
91	Midway, *San Patricio*	1¾	300	0	293,033	218,431	13	4	0	12	0	10	2
92	Mirando City, *Webb*	17	1,430	500	8,889,345	154,773	295	0	6*y*	79	1	0	79
93	Mirando Valley, *Zapata*	17¾	200	200	713,929	70,842	60	11	1	18	2	4	14
94	Moca, *Webb*	6	80	20	868,808	132,577	12	0	0	11	0	0	11
95	Munson, *McMullen*	⅛	100	20	9,826	9,826	10	10	0	5	1	0	5

[6] Includes South Hoffman. [7] Includes North Jacob. [8] Includes North (Deep) Kohler.

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d] Initial	Character of Oil, Approx. Average: Gravity A.P.I. at 60° F. Weighted Average	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Wells	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
58	475	23	Hockleyensis	Eoc	2,688	2,550	Ss	Por	20	ML	Cockfield	3,605
		23	Govt. Wells	Eoc	2,760	2,720	Ss	Por	12			
		27.1	Loma Novia	Eoc	2,895	2,820	Ss	Por	30			
59	1,100	45	Rosenburg (Pettus)	Eoc	2,524	2,492	Ss	Por	23	ML	Pettus	2,524
60		Gas	Mirando	Eoc	790	780	Ss	Por	8	ML	Mt. Selman	3,171
		21.5	Pettus	Eoc	975	920	Ss	Por	7			
		21	Cockfield	Eoc	1,070	1,050	Ss	Por	8			
61		22	McElroy	Eoc	1,240	905	Ss	Por	20	A	Reklaw	4,645
		23	Jackson-Cockfield	Eoc	1,953	1,410	Ss	Por	15			
62		44.7	Frio	Olig	4,748	4,697	Ss	Por	16	A	Vicksburg	5,274
63	225	21.5	Mirando	Eoc	2,035	1,920	Ss	Por	12	ML	Cockfield	2,657
64		22	Mirando	Eoc	2,051	2,046	Ss	Por	6½	ML	Jackson	2,112
65		21.5	Miocene	Mio	2,900	1,400	S	Por	20	D	Frio	6,922
		22	Oligocene	Olig	3,238	3,217	Ss	Por	20			
66		21.5	Cole	Eoc	1,850	1,748	Ss	Por	12	ML	Carrizo	7,723
		22.5	Govt. Wells	Eoc	2,500	2,438	Ss	Por	12			
	320	21.6	Mirando	Eoc	2,800	2,613	Ss	Por	29			
67	890	Gas	Hockleyensis	Eoc	2,460	2,453	Ss	Por	7	ML	Yegua	4,054
	260	27	Loma Novia	Eoc	2,900	2,800	Ss	Por	19			
68		56	Frio	Olig	6,683	6,650	Ss	Por	20	D	Vicksburg	8,893
			Frio	Olig	7,875	7,840	Ss	Por	20			
69	2,125	51.6	Frio	Olig	5,969	5,917	Ss	Por	52	AF	Vicksburg	7,010
70	200	18.7	Cole	Eoc	1,828	1,782	Ss	Por	22	A	Yegua	3,808
71	2,056	48	Frio	Olig	7,646	7,630	S	Por	16	Ds	Frio	10,286
72		Gas	Frio	Olig	366	360	Ss	Por	6	MF	Mt. Selman	3,165
		Gas	Mirando	Eoc	1,777	1,770	Ss	Por	6			
		49	Cockfield	Eoc	2,275	2,244	Ss	Por	7			
73		22	McElroy	Eoc	1,055	1,049	Ss	Por	6	ML	Yegua	3,034
74	235	21	Chernosky-Govt. Wells	Eoc	2,232	2,195	Ss	Por	12	MF	Cockfield	2,766
75	200	26	Loma Novia	Eoc	2,705	2,550	Ss	Por	25	ML	Cook Mt.	4,200
		22.5	Mirando	Eoc	2,900	2,846	Ss	Por	15			
76	450	Gas	Cole	Eoc	1,812	1,790	Ss	Por	19	NL	Whitsett	1,850
77		26	Loma Novia	Eoc	2,922	2,914	Ss	Por	7½	ML	Cook Mt.	4,732
78	750	25.3	Catahoula	Olig	4,730	4,698	Ss	Por	8	Nf	Frio	7,424
	1,625	51	Catahoula	Olig	4,906	4,752	Ss	Por	10			
79	780	44.9	Govt. Wells	Eoc	4,899	4,893	Ss	Por	6	AF	Govt. Wells	4,899
80	925	Gas	Queen City	Eoc	2,170	2,147	Ss	Por	23	A	Carrizo	3,502
81	760	22	Mirando	Eoc	2,144	2,126	Ss	Por	18	ML	Yegua	3,437
82	120	18.5	Frio	Olig	694	371	Ss	Por	17	MF	McElroy	2,612
83		24	Govt. Wells	Eoc	2,196	2,166	Ss	22–26	15	MF	Govt. Wells	2,196
84	1,710	49	Catahoula	Olig	4,354	4,308	Ss	Por	15	NF	Frio	7,595
			Heterostegina	Olig	5,070	5,030	Ss	Por	20			
			Heterostegina	Olig	5,175	5,171	Ss	Por	4			
85	640	21	Cole	Eoc	1,530	1,513	Ss	Por	10	MF	Jackson	2,698
86	620	Gas	Hockleyensis	Eoc	1,927	1,921	Ss	Por	6	ML	Yegua	3,514
87	935	Gas	Miocene	Mio	2,414	2,375	Ss	Por	10	MF	McElroy	5,526
88	2,025	Gas	Frio	Olig	5,994	5,970	S	Por	24	D	Vicksburg	7,507
	1,750	Gas	Frio-Vicksburg	Olig	7,498	6,920[10]	S	Por	25			
89	2,500	49.2	Frio	Olig	7,524	7,430	SH	Por	16	D	Vicksburg	9,618
	2,750	Distillate and gas	Frio-Vicksburg	Olig	9,000	7,920[10]	SH	Por	15			
90	1,840	Gas	Frio	Olig	6,748	6,658	Ss	Por	90	D	Frio	8,110
91	1,985	29	Frio	Olig	5,370	5,323	Ss	Por	15	D	Frio	7,003
92		21.5	Hockleyensis	Eoc	1,540	1,530	Ss	Por	10	ML	Reklaw	5,000
		45	Cockfield	Eoc	1,935	1,925	Ss	Por	10			
93	35	21	Hockleyensis	Eoc	1,425	1,415	Ss	Por	7	ML	Cook Mt.	3,660
		23	Cockfield	Eoc	1,881	1,873	Ss	Por	8			
94		21	McElroy	Eoc	910	900	Ss	Por	10	MF	Yegua	2,178
95		22.5	Mirando	Eoc	1,213	1,201	Ss	Por	12	ML	Pettus	1,501

[10] Found productive on tests—not producing.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres: Oil	Area Proved, Acres: Gas[6]	Total Oil Production, Bbl.[1]: To End of 1938	Total Oil Production, Bbl.[1]: During 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Producing Oil[5]	At End of 1938: Producing Gas[6]	Oil-production Methods at End of 1938, Number of Wells: Flowing	Oil-production Methods at End of 1938, Number of Wells: Pumping
96	Oilton, *Webb*	1⅓	1,420	80	807,480	695,931	140	65	3	132	3	0	132
97	Palangana, *Duval*	10½	50	0	9,846	0	5	0	0	0	0	0	0
98	Pena, *Duval*	6	0	40	Gas		1	0	0	0	0	0	0
99	Peters, *Duval*	6	120	1,400	132,953	42,079	19	2	0	6	2	6	0
100	Peyote, *Jim Hogg*	6¼	0	20	Gas		1	0	0	0	0		
101	Piedre Lumbre, *Duval*	3¼	640	200	861,261	353,978	81	15	1	72	5	25	47
102	Pietras Pintas, *Duval*	33¼	120	0	150,927	305	25	0	0	1	0	0 0	0 1
103	Plymouth, *San Patricio*	3¾	3,320	0	13,581,259	4,477,864	166	19	0	164	0	164	0
104	East Plymouth, *San Patricio*	⅔	0	20	Gas	Gas	1	1	0	0	1		
105	Premont, *Jim Wells*	5¾	500	80	475,407	178,920	41	6	1	29	4	5	24
106	East Premont, *Jim Wells*	1	200	0	59,778	58,778	5	4	0	3	0	3	0
107	Rancho Sold, *Duval*	3	200	120	41,206	24,462	20	9	0	9	1	5	4
108	Randado, *Jim Hogg*	12¾	765	435	4,558,018	92,239	191	0	7*y*	90	0	0	90
109	Reiser, *Webb*	30	20	1,270	4,000	0	18	0	0	0	0	0	0
110	Rhode, *McMullen*	2⅔	0	650	Gas	Gas	9	3	0	0	8		
111	Ricaby, *Starr*	2	40	0	7,854	2,555	4	2	0	4	0	0	4
112	Richard King, *Nueces*	1	200	50	134,123	129,386	12	10	0	8	2	8	0
113	Rincon, *Starr*	1	50	0	11,624	11,624	1	1	0	0	0		
114	Rio Grande City, *Starr*	6⅔	150	0	347,940	27,958	30	0	2	15	0	0	15
115	Riverside, *Nueces*	0	0	40	Gas	Gas	2	2	1[15]	0	1		
116	Roma, *Starr*	11¼	20	280	18,144	1,951	5	0	0	1	0	0	1
117	Sacatosa, *Starr*	¼	0	10	Gas	Gas	1	1	0	0	1		
118	Sam Fordyce,[12] *Starr-Hidalgo*	4¼	1,600	900	6,550,123	1,315,831	239	40	*y*	154	12	69	85
119	Sandia, *Jim Wells*	9	50	50	20,737	6,945	6	0	0	2	3	1	1
120	San Diego, *Jim Wells*	3	0	120	Gas		2	0	0	0	2		
121	San Jose, *McMullen*	⅓	10	10	450	450	2	2	0	0	1		
122	San Salvador, *Hidalgo*	¾	20	0	*y*	*y*	1	1	0	0	0		
123	Santo Domingo, *Starr*	3	0	50	Gas	Gas	2	1	0	0	2		
124	Sarnosa, *Duval*	6¾	690	180	2,060,623	225,859	57	1	0	51	0	0	51
	Saxet, *Nueces:*												
125	Shallow	16	3,650	3,350	31,864,718 (125 and 126 together)	10,740,102	722	72	*y*	366	28	215	151
126	Deep	3½	2,350	650						216	8	180	36

[12] Includes North Sam Fordyce. [15] Crater (discovery).

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d] Initial	Character of Oil, Approx. Average: Gravity A.P.I. at 60° F. Weighted Average	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
96	300	22	Mirando	Eoc	2,000	1,885	Ss	Por	12	ML	Yegua	3,000
	850		Cockfield	Eoc	2,473	2,407	Ss	Por	15			
97		16	Catahoula	Olig	455	450	L	Cav	5	DS	Mt. Selman	5,454
	200	45	Jackson	Eoc	2,744	2,730	Ss	Por	14			
98	700	Gas	Frio	Olig	1,932	1,915	Ss	Por	17	MF	Caddell	3,620
99		Gas	Cole	Eoc	1,760	1,750	Ss	Por	5	ML	Yegua	3,309
	750	Gas	Govt. Wells	Eoc	2,451	2,431	Ss	Por	20			
		23	Mirando	Eoc	2,635	2,610	Ss	Por	15			
100		Gas	Govt. Wells	Eoc	2,262	2,246	Ss	Por	16	ML	Yegua	3,210
101	500	Gas	Cole	Eoc	1,350	1,324	Ss	Por	7	ML	Yegua	3,250
		20.5	Govt. Wells	Eoc	1,975	1,962	Ss	Por	12			
	400	22.5	Loma Novia	Eoc	2,139	2,133	Ss	Por	10			
102		13	Catahoula	Olig	580	180	Ss	Por	20	DS	Mt. Selman	4,502
	500	47	Jackson-Cockfield	Eoc	3,623	3,462	Ss	Por	26			
103	2,200	32	Frio	Olig	5,508	5,501	Ss	Por	7y	MC	Frio	7,253
	1,100	34.2	Frio	Olig	5,663	5,659	Ss	Por	4y			
		38	Frio	Olig	5,911	5,907	Ss	Por	4y			
	650	40	Frio	Olig	6,159	6,156[11]	Ss	Por	3y			
104	1,950	24.5	Heterostegina	Olig	4,836	4,808	Ss	28–34	20	AF	Frio	6,750
105	800	22.8	Catahoula	Olig	2,350	2,250	Ss	Por	10	D	McElroy	7,135
	900	24	Frio	Olig	3,265	3,165	Ss	Por	11			
106	2,000		Frio	Olig	5,370	5,365[13]	Ss	Por	5y	D	Vicksburg	8,162
	1,975	36	Frio	Olig	5,632	5,626[13]	Ss	Por	6y			
	2,200		Frio	Olig	6,138	5,807[14]	Ss	Por	5y			
	2,000		Vicksburg	Olig	6,694	6,582	Ss	Por	10y			
107		21.5	Cole	Eoc	1,856	1,826	Ss	Por	12	ML	Yegua	3,777
	800	Gas	Govt. Wells	Eoc	2,569	2,555	Ss	Por	14			
108		20.5	Cole	Eoc	1,275	1,225	Ss	Por	9	MF	Mt. Selman	5,222
109		16	Jackson-Cockfield	Eoc	1,010	390	Ss	Por	15	ML	Mt. Selman	3,247
110	650	Gas	Cole	Eoc	1,822	1,800	Ss	Por	12	MF	Yegua	3,534
111	175	23	Frio	Olig	1,317	1,312	Ss	Por	5	ML	Frio	2,011
	235	30	Frio	Olig	1,611	1,604	Ss	Por	7			
112		22	Frio	Olig	4,015	4,000	SH	Por	15	NF	Hockleyensis	7,567
113	1,700	59	Vicksburg	Olig	4,259	4,172	Ss	26–39	40	A	Jackson	6,862
114		27.3	Frio	Olig	1,450	1,350	Ss	Por	8	MF	Jackson	3,258
115	1,450	Gas and distillate	Frio	Olig	4,893	4,888[13]	Ss	Por	10y	A	Frio	7,015
116			Frio-Jackson	Olig-Eoc	200	192	Ss	Por	8	A	Reklaw	4,827
		35	Queen City	Eoc	3,590	3,560	Ss	Por	6			
117	400	Gas	Govt. Wells	Eoc	1,661	1,650	Ss	Por	11	N	McElroy	1,794
118	400	21	Frio	Olig	2,753	2,737	Ss	Por	16	A	Yegua	9,708
	1,050	24	Frio	Olig	2,853	2,831	Ss	Por	22			
	1,250	24.5	Frio	Olig	3,125	2,925	Ss	Por	20			
	1,150	Gas	Frio	Olig	3,196	3,183	Ss	Por	13			
	2,800	Gas	Jackson	Olig	5,900	5,840	Ss	Por	20			
119	1,050	Gas	Catahoula	Olig	2,917	2,910	Ss	Por	7	AF	Hockleyensis	5,701
	1,227	41.5	Frio	Olig	4,023	4,002	Ss	Por	13			
	1,750	52	Cole	Eoc	5,163	5,151	Ss	Por	9			
120	1,200	Gas	Frio	Olig	2,976	2,952	Ss	Por	10	A	Yegua	6,480
121	245	23	Cole	Eoc	1,163	1,147	Ss	Por	16	ML	Jackson	2,012
122	3,200	Gas	Frio	Olig	7,645	7,630	Ss	Por	15	A	Frio	8,002
123	1,050	Gas	Frio	Olig	2,616	2,461	Ss	Por	25	A	Jackson	4,003
124		22	Govt. Wells	Eoc	2,412	2,350	Ss	Por	40	MF	Yegua	4,073
125	1,325	24	Lagarto-Oakville	Mio	3,150	1,000	Ss	Por	10y	DF	Vicksburg y	10,042[17]
		24	Catahoula	Olig	4,500	3,900	Ss	Por	18y			
			Discorbis-Het.	Olig	4,880	4,700	Ss	Por	18y			
126	2,000		Frio	Olig	6,900	5,500	Ss	Por	18y			
	2,300	48	Frio	Olig	7,390	7,250	Ss	Por	140y			
	3,400		Vicksburg (y)	Olig	9,927	y	Ss	Por	y			

[11] Perforations. [13] Perforations. [14] Found productive on tests—not producing. [17] Drilling.

perforations at 2800 to 2807 ft. This and other wells materially extended the Hoffman field during the year in a south and southwest direction, connected it with the South Hoffman area, and indicated that its several sands, from the top of the *Hockleyensis* into the Loma Novia sand, will cover a large area. The field has been the center of an extensive development program of both inside and outpost wells.

Benavides Field.—In February, the 3800-ft. Cole sand was proven productive of oil by Republic Natural Gas Company's No. A-2 Buoy, in the southern part of the field, flowing 600 bbl. of oil per day from sand

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres: Oil	Area Proved, Acres: Gas[a]	Total Oil Production, Bbl.[1]: To End of 1938	Total Oil Production, Bbl.[1]: During 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Producing Oil[b]	At End of 1938: Producing Gas[c]	Oil-production Methods at End of 1938, Number of Wells: Flowing	Pumping
127	Seven Sisters, *Duval*....	3⅔	4,420	120	8,467,090	2,739,397	444	4	0	412	2	125	287
128	South Seven Sisters, *Duval*................	1¾	330	0	219,878	211,740	33	30	0	33	0	5	28
129	Sinton, *San Patricio*....	4⅔	225	100	77,498	4,657	7	0	0	1	0	1	0
130	Stratton, *Nueces*.......	7	250	50	151,975	129,990	9	4	0	7	1	6	0
131	Sullivan (South Agua Dulce), *Nueces*.......	2¼	120	680	77,378	43,836	3	1	0	3	0	3	0
132	Sun, *Starr*.............	¼	100	0	11,695	11,695	4	4	0	4	0	4	0
133	Sweden, *Duval*.........	2	150	100	146,028	93,240	12	3	1	7	2	2	5
134	Taft, *San Patricio*......	3	720	10	2,367,618	780,761	73	4	0	70	1	66	4
135	Tesoro, *Duval*..........	½	60	0	27,306	27,306	4	4	0	4	0	4	0
136	Thomas Lockhart, *Duval*	1¾	100	0	16,991	5,001	4	0	0	3	0	1	2
137	Turkey Creek, *Nueces*..	1	750	20	845,857	845,857	53	53	0	52	1	45	7
138	Villa, *Zapata*..........	6¼	0	120	Gas		3	0	0	0	0		
139	Wentz, *McMullen*......	7	0	80	Gas		3	0	0	0	0		
140	Weslaco, *Hidalgo*.......	1	20	0	1,988	1,988	1	1	0	0	0		
141	White Point, *San Patricio*..............	8	60	3,865	116,454	20,231	46	1	0	1	39	0	1
142	East White Point, *San Patricio*..............	1	600	0	368,463	368,463	30	30	0	30	0	30	0
143	Woods, *Starr*..........	2½	0	120	Gas		4	0	0	0	0		
144	Wray, *Zapata*..........	5½	0	80	Gas		3	0	0	0	0		
145	Young (Charco Blanco), *Starr*................	½	0	20	Gas	Gas	1	1	0	0	0		
146	Total............		83,960	58,985	217,887,983	56,152,122	9,426*y*	1,274	65*y*	6,675*y*	432*y*	2,310	4,341

at 3870 to 3880 ft., a level which heretofore had produced only gas. An extension ½ mile east was provided through the completion of Hiawatha Oil Company's No. 9 Parr, which flowed 115 bbl. of oil daily from perforations at 5510 to 5515 ft. in Pettus sand at 5505 to 5518 ft. Production was obtained through ⅛-in. choke under pressures of 550 lb. on tubing and 850 lb. on casing. These and other extensions, in addition to the large area already proved, provided ample space for an extensive drilling campaign in this field. Of the several producing sands, the 5300-ft. Pettus zone provided the greatest number of completions during 1938.

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d] Initial	Character of Oil, Approx. Average: Gravity A.P.I. at 60° F. Weighted Average	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
127	225	21	Cole	Eoc	1,720	1,710	Ss	Por	10	MF	Yegua	4,404
		20.5	Chernosky	Eoc	2,225	2,112	Ss	Por	20			
	625	23	Gov. Wells	Eoc	2,485	2,470	Ss	Por	15			
	200	27	Loma Novia	Eoc	2,690	2,660[16]	Ss	Por	15			
	460	23	Mirando	Eoc	2,565	2,540[16]	Ss	Por	10			
128		22	Frio	Olig	1,566	1,559	Ss	Por	7	MF	Pettus	3,100
		27	Loma Novia	Eoc	2,656	2,646	Ss	Por	10			
129	2,200	47	Frio	Olig	5,905	5,425	Ss	Por	10	D	Frio	7,438
130	1,850		Frio	Olig	4,801	4,788	Ss	Por	13	L	Frio	6,904
	2,110	58	Frio	Olig	6,002	5,992	Ss	Por	10			
	1,900		Frio	Olig	6,300	6,273	Ss	Por	27			
			Frio	Olig	6,485	6,481	Ss	Por	4			
131	2,000	43	Frio	Olig	5,780	5,756	Ss	Por	15	DF	Frio	6,912
	2,300	Gas	Frio	Olig	6,788	6,410	Ss	Por	10			
132	730	41.8	Frio	Olig	4,858	4,842	Ss	Por	16	A	Vicksburg	5,709
	450	44	Frio	Olig	4,911	4,901	Ss	Por	10			
	2,000	47.9	Vicksburg	Olig	5,135	5,115	Ss	Por	20			
133	120	43	Chernosky	Eoc	4,915	4,895	Ss	Por	20	AF	Yegua	6,531
		46	Upper Govt. Wells	Eoc	5,091	5,072	Ss	Por	19			
	300	Gas	Lower Govt. Wells	Eoc	5,116	5,100	Ss	Por	16			
	710	58	Cockfield	Eoc	5,869	5,845	Ss	Por	24			
134	600	24	Catahoula	Olig	4,300	3,950	Ss	Por	20	DF	Frio	6,926
	375	24.5	Heterostegina	Olig	4,938	4,872	SH	Por	20			
135	670	45	Pettus	Eoc	5,136	5,108	Ss	Por	20	NF	Yegua	5,541
136	1,450	56.8	Pettus	Eoc	4,672	4,659	Ss	Por	13	MF	Yegua	5,502
137	550	25	Catahoula	Olig	4,080	3,846	Ss	Por	14	DF	Frio	7,511
	1,400	35.2	Frio	Olig	5,841	5,641	Ss	28	19			
	780	28	Frio	Olig	6,456	6,430	Ss	Por	26			
138	375	Gas	McElroy	Eoc	1,664	1,657	Ss	Por	7	ML	Cook Mt.	3,000
139	200	Gas	Cole	Eoc	382	370	Ss	Por	12	N	Yegua	1,654
140	2,950	51	Frio	Olig	9,005	8,634	Ss	23–27	15	A	Vicksburg	9,182
141	765	Gas	Lagarto-Oakville	Mio	2,800	1,900	Ss	Por	10	D	Frio	7,211
	2,000	31	Heterostegina	Olig	4,961	4,880	Ss	Por	10			
142	950	38.5	Frio	Olig	5,665	5,630	Ss	24–33	30	AF	Frio	5,716
143	460	Gas	Frio	Olig	975	963	Ss	Por	12	A	Jackson	3,360
144	150	Gas	Jackson	Eoc	370	348	Ss	Por	22	ML	Mt. Selman	2,000
145	960	Gas	Jackson	Eoc	2,730	2,708	Ss	Por	15	MF	Jackson	3,008
146												

[16] Due to elevation.

TABLE 2.—*Summary of Drilling Operations in South Texas in 1938*

Important Wildcats Drilled in 1938

	County	Well Name and Location	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
	LAREDO DISTRICT				
1	Duval	Hagist No. 5 B. S. & F. Survey	2,196	Catahoula	Jackson
2	Duval	Fitzsimmons No. 1 Sec. 291	4,303	Goliad	Pettus
3	Duval	DCRC No. 1 Sec. 291	1,190	Catahoula	Cole
4	Duval	Cuellar Bros. No. 1 Sec. 96	5,520	Goliad	Yegua
5	Duval	DCRC No. 2 Sec. 189	1,451	Goliad	Cole
6	Duval	Miller No. 1 1½ miles SW. Sweden field	4,899	Goliad	Govt. Wells
7	Duval	Foster No. 1 Sec. 206	1,539	Catahoula	Whitsett
8	Duval	Worden & Drought No. 20 Sec. 151	1,101	Catahoula	Hockleyensis
9	Duval	Martin No. 1 Sec. 230	1,207	Catahoula	Cole
10	Duval	Fitzsimmons No. 2A.	3,610	Goliad	Chernosky
11	Duval	Miller No. 5 Sec. 23	5,984	Goliad	Cockfield
12	Duval	W. R. Peters No. 1 Sec. 29	3,200	Goliad	Jackson
13	Duval	Clara Driscoll No. 1 Sec. 292	4,334	Goliad	Pettus
14	Duval	Southland No. 6 Sec. 12	5,513	Goliad	Cockfield
15	Duval	Merle West No. 2	4,532	Goliad	Jackson
16	Duval	L. C. Lape No. 1 Sec. 497	2,807	Goliad	Loma Novia
17	Jim Hogg	A. Kelsey No. 2 San Rafael Grant	4,754	Sand Dunes	Basal Frio
18	Jim Hogg	A. K. Bass No. 3	5,274	Sand Dunes	Vicksburg
19	Jim Hogg	J. P. DeGarza No. 1 El Bar Oil Co. Subd.	5,005	Sand Dunes	Frio-Vicksburg
20	Jim Hogg	F. G. Martinez No. 1 Sec. 623	3,015	Catahoula	Cockfield
21	McMullen	Kountz No. 2 Sec. 123	2,012	Catahoula	Jackson
22	McMullen	Nueces L. & L. Co. No. 1 Sec. 119	1,213	Frio	Mirando
23	McMullen	H. C. Edrington No. 1 Survey 57	2,519	Lagarto	Govt. Wells
24	McMullen	M. Gordon No. 3 Sec. 127	2,232	Catahoula	Jackson
25	McMullen	H. Ezzell No. E-1 Sec. 24	1,543	Catahoula	Loma Novia
26	McMullen	H. Ezzell No. F-1 Sec. 29	1,527	Catahoula	Loma Novia
27	McMullen	Fee No. 22 Sec. 35	1,534	Catahoula	Loma Novia
28	McMullen	H. Ezzell No. 40	1,534	Catahoula	Loma Novia
29	McMullen	H. C. Edrington No. 1, No. 1,823	1,823	Catahoula	Cole
30	Starr	Slick School No. 1 Sec. 266	6,862	Goliad	Jackson
31	Starr	Young No. 1 Porcian No. 79	3,008	Goliad	Jackson
32	Starr	F. B. Guerra No. 1-A Share No. 20	7,010	Goliad	Vicksburg
33	Starr	Mrs. A. McKinney No. 1 Survey 242	4,858	Goliad	Basal Frio
34	Starr	Zaragosa and Salinas No. 2 Sacatosa Grant	1,705	Frio	Govt. Wells
35	Starr	Garza No. 1 Sec. 956	2,669	Goliad	Frio
36	Starr	A. Flores No. 3	3,364	Goliad	Frio
37	Starr	Fee Guerra No. 1	5,942	Goliad	Frio
38	Starr	Sheldon No. 1 Porcian No. 41	3,015	Goliad	Frio
39	Starr	S. Olivares No. 1	5,150	Goliad	Vicksburg
40	Starr	Olivares No. 1	5,709	Goliad	Vicksburg
41	Webb	Bruni No. 3 Sec. 449	1,850	Goliad	Jackson
42	Webb	Garcia and Villareal No. 1 Sec. 720	2,524	Frio	Cockfield
43	Webb	Guerra No. 1 Survey 334	2,112	Frio	Mirando
44	Webb	Laurel Bros. No. 1 Sec. 333	2,020	Frio	Mirando
45	Webb	S. Benavides No. 1 Block 18	3,445	Goliad	Yegua
46	Webb	E. M. Thompson No. 5 Sec. 1,005	2,482	Frio	Rosenburg
47	Zapata	R. Lopez No. 1 Sec. 253	1,881	Frio	Cockfield
	SOUTH CORPUS CHRISTI DISTRICT				
48	Brooks	McGill No. 1 (Kelsey Area)	4,728	Sand Dunes	Frio
49	Hidalgo	Argli No. 1 Sec. 175	9,005	Beaumont	Frio
50	Hidalgo	Cardenas No. 1	8,003	Beaumont	Frio
51	Hidalgo	W. W. Woody No. 1 Porcian No. 69	7,214	Beaumont	Vicksburg
52	Hidalgo	E. M. Card No. 1	7,507	Beaumont	Vicksburg
53	Hidalgo	Flores No. 1 (Sam Fordyce)	9,708	Goliad	Yegua (*y*)
54	Hidalgo	Argli No. 11 (Mercedes)	9,618	Alluvium	Vicksburg
55	Jim Wells	Robt. Adams No. 1 Sec. 19	5,509	Lissie	Jackson
56	Jim Wells	Mortgage Investment No. 1 La Vaca Grant	3-496	Lissie	Frio
57	Jim Wells	Lindsay & Reed No. 1 La Vaca Grant	5,430	Lissie	Vicksburg
58	Jim Wells	P. G. de Valadez La Anima Solo Grant	6,419	Lissie	Jackson
59	Jim Wells	H. J. Mosser No. 1 Collins Subd.	7,335	Lissie	Cockfield
60	Jim Wells	Stillwell No. 1 Block 17	5,452	Lissie	Vicksburg

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	Drilled by	Initial Production per Day: Oil, U. S. Bbl.	Initial Production per Day: Gas, Millions Cu. Ft.	Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.: Casing	Pressure, Lb. per Sq. In.: Tubing	Remarks
1	V. G. Schimmel	28		Pumping			Opened Los Pichacos field
2	H. J. Porter	108		9/64	1,020	370	Opened Fitzsimmons field
3	Magnolia Petr. Co.	74		Pumping			Opened Casa Blanca field
4	Arkansas Fuel Co.	95		3/8	670	150	Opened Tesoro field
5	Magnolia Petr. Co.	50		Pumping			Opened Cedro Hill field
6	Longhorn Drilling Co.	203		5/32	1,000	780	Opened Longhorn field
7	V. G. Schimmel	107		Pumping			½ mile ext. Eagle-Hill
8	N. V. Duncan	65		Pumping			New sand, Charamousca
9	Creighton & Moore	137		Pumping			¾ mile North ext. Casa Blanca
10	H. J. Porter	55		1/4	1,325	1,200	New Sand, Fitzsimmons
11	Hiawatha Oil Co.	50		1/4	120		New Sand and West ext. Sweden
12	Stewart & Nye	105		Pumping			East ext. Rancho Solo
13	H. J. Porter	190		1/4	650	250	NE. Ext. Fitzsimmons
14	Hiawatha Oil Co.	350		1/8	800	525	New 5,500-ft. sand Benavides
15	Circle Oil Co.	500		9/64	1,525	925	4,500-ft. sand Benavides
16	W. A. Wagner	200					1 Mile South ext. Hoffman
17	Humble Ref. Co.	164		1/8	1,420	1,170	Opened Kelsey field
18	Humble Ref. Co.	135		3/16			North Ext. Kelsey
19	Navarro Oil Co.						Dry Hole between Kelsey and Sun fields
20	K. D. Harrison	60		Open tubing	145	20	Ext. Colorado
21	V. G. Schimmel	5	3	1/4	295	245	Opened San Jose field
22	Bruce Albright	80		Pumping			Opened Munson field
23	Wm. H. Spice	50		1/2–5/8	280	140	Opened Campana field
24	W. A. Wagner	50		Pumping			New Sand and ext. Loma Alta
25	Edwin M. Jones	150		Pumping			SW. ext. Ezzell
26	Edwin M. Jones	525		Pump and flow			SW. ext. Ezzell
27	Harry Ezzell	892		Open tubing	385	75	SW. ext. Ezzell
28	Edwin M. Jones	150		Pumping			SW. ext. Ezzell
29	Loma Oil Co.		23		600 (rock pressure)		South ext. Rhode
30	Transwestern	1	5	1/4	1,125	1,425	Opened Rincon field
31	Sun Oil Co.		3	5/16	1,000	960	Opened Young field
32	Wheelock & Collins	60	2½	3/16	2,300	2,125	Opened La Reforma field
33	Sun Oil Co.	180		5/32	990	730	Opened Sun field
34	Harvey & Henderson		5	1/4	400	650	Opened Sacatosa field
35	Lee Davis	375		1/8	410	160	Opened North Barbacoas
36	H. J. Porter		15		1,150		New sand, Sam Fordyce
37	Magnolia Petr. Co.	75	9	7/32	2,100	1,750	SW. ext. La Reforma
38	H. C. Dean	240		1/8	700	200	Between Sam Fordyce and North Sam Fordyce
39	Circle Oil Co.	150		1/8	1,325	2,000	New 5,100-ft. Sand, Sun field
40	Sun Oil Co.	132		5/32	1,250	450	New 4,900-ft. Frio Sand, Sun field
41	Howard Nessley		7	3/8	450	400	Opened Loma Valdez field
42	W. F. Houser	(several)	15	1/4	1,100	800	Opened Houser field
43	Dovre, Brown & Taylor Ref. Co.	142		Pumping			Opened North Killam field
44	M. E. Morton	20	5	1/4	450	450	NW. ext. Killam
45	D. P. Kenyon	200		3/16	900	900	New sand, Bruni
46	O. W. Killam & Campbell	(several)					First Rosenburg sand test, main Oilton field
47	Bert Calvin	150				35	New sand (Cockfield), Mirando Valley
48	Humble Ref. Co.	216		3/16	1,100	750	Extended Kelsey field into Brooks County
49	Atlantic Ref. Co.	61	7½	3/8	2,450	2,425	Opened Weslaco field
50	Gulf States	110	5.8	5/16	3,300	3,200	Opened San Salvador field
51	Harding & Pantano	24	2.5	3/8	2,050	2,025	Opened McAllen field
52	R. E. Harding	180	5½	3/8	(sealed)	1,750	New sands, McAllen
53	Phillips Petr. Co.	50	2.26	3/16	2,800 (working)		Deepest test and new sand, Sam Fordyce
54	Union Prod. Co.	35	3	3/8	1,300	1,100	Deepest test and new sands, Mercedes
55	Rowan & Hope	125		5/32	340	125	Opened Alfred field
56	Presnall & Mosser	4	2.8	3/16	1,400	1,350	} Co-discoveries of Alice field
57	H. H. Howell	177		1/8	1,085	900	} Co-discoveries of Alice field
58	Magnolia Petr. Co.		40	2 inch tubing	3,635	3,550	Opened Bandera field
59	H. H. Howell	160		3/16	1,400	750	New 4,700-ft. sand, Alice
60	Southern Minerals	600					New Vicksburg sand, Alice

Jim Hogg County

Kelsey Field.—The Kelsey field, situated on the Kelsey anticline in southeastern Jim Hogg County, was discovered by Humble Oil & Refining Company's A. K. Bass No. 2, San Rafael grant, which was completed for a flow of 164 bbl. of 44.7° gravity oil per day through perforations at 4744 to 4748 ft. in Frio sand at 4730 to 4748 ft. The well showed 1170 lb. pressure on tubing and 1480 lb. pressure on casing while flowing

Table 2.—(*Continued*)

Important Wildcats Drilled in 1938

	County	Well Name and Location	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested
61	Jim Wells	Rattan No. 2 Block 13	5,312	Lissie	Vicksburg
62	Jim Wells	Dunlap No. 1 Sec. 181	6,766	Lissie	Vicksburg
63	Jim Wells	Smith & Gardner No. 2	5,618	Lissie	Vicksburg
64	Jim Wells	R. V. de Garcia No. 1	8,302	Lissie	Yegua (*y*)
65	Jim Wells	Seeligson No. 10 (East Premont)	6,602	Lissie	Vicksburg
66	Jim Wells	Bankers Mortgage No. 1 Clegg Subd.	5,402	Lissie	Vicksburg
67	Jim Wells	Martens No. 1 (Alice)	3,533	Lissie	Frio
68	Jim Wells	Lindsey & Reed No. 1 (Alice)	5,370	Lissie	Vicksburg
69	Jim Wells	Cook No. 1 (Alice)	5,500	Lissie	Vicksburg
70	Jim Wells	Robt. Adams No. 1 (Alfred)	3,372	Lissie	Frio
71	Jim Wells	Seeligson No. 8	6,953	Lissie	Vicksburg
72	Kleburg	State of Texas No. 1 Tract 522	9,636	(Submerged)	Frio
73	Nueces	Chas. McKenzie No. 1 Survey 419	5,813	Beaumont	Frio
74	Nueces	Simmons No. 1 Agua Dulce Grant	8,706	Beaumont	Vicksburg
75	Nueces	E. C. Wilson No. 1 Herrera Grant	6,541	Beaumont	Frio
76	Nueces	H. B. Baldwin No. 4 Block 20	5,167	Beaumont	Heterostegina
77	Nueces	C. P. Wardner No. 4 Sec. 16	6,300	Beaumont	Frio
78	Nueces	John Dunn No. 1 Survey 422	5,832	Beaumont	Frio
79	Nueces	Fee No. 1	5,859	Beaumont	Frio
80	Nueces	C. L. Galladay No. 1	8,190	Beaumont	Vicksburg
81	Nueces	Perkins No. 1	4,902	Beaumont	Frio
82	Nueces	L. McKinzie No. 1 Survey 422	5,814	Beaumont	Frio
83	Nueces	Dugger No. 2	5,505	Beaumont	Frio
84	Nueces	McKinzie No. 1	5,821	Beaumont	Frio
85	Nueces	Torbett No. 1 Sec. 31	7,700	Beaumont	Vicksburg
86	Nueces	State No. 1 (Laguna-Madre)	6,666	(Submerged)	Frio
87	Nueces	Fee No. 2-C Lot 45	5,975	Beaumont	Frio
88	Nueces	Taggart No. 1-B	6,841	Beaumont	Frio
89	Nueces	McCann No. 1	5,065	Beaumont	Heterostegina
90	Nueces	Isensee No. 4 Sec. 402	6,942	Beaumont	Frio
91	Nueces	M. Erigan No. 2 Block 40	7,999	Beaumont	Frio
92	Nueces	State No. 1 Red Fish Bay	8,660	(Submerged)	Frio
93	Nueces	M. S. T. Kenedy No. 2-B	6,456	Beaumont	Frio
94	Nueces	A. D. Halloway No. 1	5,385	Beaumont	Frio
95	Nueces	F. J. Smith No. 1 Sec. 420	7,511	Beaumont	Frio
96	Nueces	Clark No. 1 Veg. Gard. Subd.	7,015	Beaumont	Frio
97	Nueces	Cain & Sechrist No. 24	9,927	Beaumont	Vicksburg (*y*)
98	Nueces	E. H. Sands No. 1 Sec. 86	4,675	Beaumont	Frio
99	Nueces	Minnie Brown No. 1 Sec. 87	13,728	Beaumont	Cockfield (*y*)
100	Nueces	T. M. Harrell No. 3 Block 33	10,042	Beaumont	Vicksburg (*y*)
101	San Patricio	Smith Tolbert No. 1 Sec. 37	4,836	Beaumont	Heterostegina
102	San Patricio	Brigham No. 1 Sec. 62	5,665	Beaumont	Frio
103	San Patricio	Carlock No. 1 Block 72	7,143	Alluvium	Frio
104	San Patricio	E. H. Welder No. 95-C	6,159	Beaumont	Frio
105	Willacy	Garcia Land No. 2	10,007	Alluvium	Frio
106	Willacy	Armendiaz No. 1	10,325	Alluvium	Frio

naturally through ⅛-in. choke on tubing. The company had previously abandoned a test in which gas and oil shows were found, on this same structure, but 30,000 ft. northwest of the discovery. Production on this huge anticline, which lies in a slightly northeast-southwest direction and extends through southeastern Jim Hogg, northeastern Starr, and southwestern Brooks Counties, is expected to be controlled by lenses on the structure. The producing sand in the discovery well was mostly soft and well saturated.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
		Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
61	R. B. Bryant	200		3/16	750	75	New 5,000-ft. Frio sand, Alice
62	Transwestern	400		1/4	1,975	2,000	New Sand and SW. ext. East Premont
63	Texas Gulf Prod.	450					New 5,200-ft. sand, Alice
64	Magnolia Petr. Co.		12				East ext. Bandera
65	Magnolia Petr. Co.	85		3/8	2,125	1,975	New 5,600-ft. Frio sand, East Premont
66	Tom Graham, H. Mosser	60		3/32	1,920	1,580	2-mile NE. ext. deep production, Alice
67	Tom Graham	(Distillate)	10	1/8	1,250	1,250	New Frio sand and West ext., Alice
68	W. J. Goldston	50	5	3/16	2,125	1,900	New sand, Alice
69	Pan American & Callaway	20	2½	3/16	2,200	2,175	East ext., Alice
70	Smith & Storey			1/4	600		Northeast ext., Alfred
71	Magnolia Petr. Co.	1,250		3/8		1,600	North ext. East Premont
72	Pure & Superior		75		(2,700)		Opened Bird Island field
73	L. A. Douglas	571		1/4	1,600	1,400	Opened Turkey Creek field
74	Union Prod. Co.	60	67	1/4	1,900	1,850	Opened North Agua Dulce field
75	Seaboard Oil Co.		Gas	(cratered)			Opened Riverside field
76	J. K. Culton	131		5/16	1,400	825	New sand, Corpus Christi field
77	Camp Prod. Co.	163		1/4	1,975	1,900	New sand, Stratton
78	C. Andrade III	350		9/64	1,150	850	East ext. Turkey Creek
79	Rand Morgan	250		5/32	1,105	850	New sand and south ext. Turkey Creek
80	Union Prod. Co.	36	10	1/4	2,800	2,500	Sand and north ext. Agua Dulce
81	Union Prod. Co.	50	10				West ext. Agua Dulce
82	Rutherford Oil Co.	475		11/64	1,000	950	SE. ext. Turkey Creek
83	Wellington & Seaboard	475		3/8	400	75	New sands, South Clara Driscoll
84	Heep Oil Co.	350		3/16	1,000	900	NE. ext. Turkey Creek
85	Union Prod. Co.	480		1/4	1,375	950	New 5,300-ft. sand, Agua Dulce
86	Sinclair-Prairie	500		1/8			First submerged producer (Flour Bluff) in South Texas
87	Rand Morgan	125		11/64	950	550	New 3,800-ft. sand, Turkey Creek
88	Sultex Oil Co.	800		9/64	1,330	1,200	New sand and SW. ext. Saxet
89	Sun Oil Co.	106		7/64			South ext. Luby
90	Western Gulf	145		1/8	1,300	1,000	New 6,400-ft. Frio sand, Saxet
91	Richardson Petr. Co.	500	3	1/8	2,500	2,300	New deep sand, Saxet
92	Coastline Oil			Dry hole			First submerged wildcat South Texas
93	Renwar Oil Co.	500		5/32	1,150	780	New 6,400-ft. sand, Turkey Creek
94	H. M. Reed	500			(Artificial lift)		New sand, Clara Driscoll
95	Carlos Oil	170		5/32	550	375	New 4,000-ft. sand, Turkey Creek
96	Stanolind		20	12/64	1,550	1,450	SE. ext. Riverside
97	Richardson Petr. Co.	175	3	3/16	3,400 (on drill stem)		Deepest prod. in Saxet and So. Texas
98	G. P. Sheldon	250					New Frio sand, Agua Dulce
99	Union Prod. Co.			(Plugging back)			Deepest test in Agua Dulce and So. Texas
100	Richardson Petr. Co.			(Drilling at end of year)			Deepest test Saxet
101	Humble Ref. Co.		10	5/32	2,100	1,950	Opened East Plymouth
102	Plymouth Oil Co.	216		9/16	1,100	950	Opened East White Point
103	Frank Grote	300		3/16			SW. ext. Aransas Pass
104	Plymouth Oil	180		5/32	1,100	995	New sand, Plymouth
105	Sal Vieja Oil Co.						Dry deep test
106	Magnolia Petr. Co.						Dry deep test

TABLE 3.—*Deep Wells Drilled during* 1938

County	Field	Company and Well	Depth, Ft.	Last Formation	Results
SOUTH CORPUS CHRISTI DISTRICT, WELLS DRILLED TO 7,500 FEET AND BELOW					
Hidalgo......	Weslaco (Discovery)	Atlantic Ref. Co. Amer. R.G.L. & I No. 1	9,182	Vicksburg	Oil and gas
Hidalgo......	San Salvador (Discovery)	Gulf States Oil Co. Cardenas No. 1	8,002	Frio	Oil and gas
Hidalgo......	Mercedes	Union Sulphur Co. Amer. R.G.L. & I No. 13	7,516	Frio	Oil and gas
Hidalgo......	La Blanca	Pantano Oil Co. Engleman No. 1-B	7,853	Frio	Oil
Hidalgo......	Wildcat	Wheelock & Collins & Magnolia Temple Lumber Co. No. 1	7,506	Frio	Dry
Hidalgo......	Sam Fordyce	Phillips Petr. Co. Rafael Flores No. 1	9,708	Yegua	Oil and gas
Hidalgo......	Mercedes	Union Sulphur Co. Amer. R.G. L. & I. No. 11	9,618	Vicksburg	Oil and gas
Hidalgo......	McAllen	R. E. Harding Card No. 1	7,507	Vicksburg	Oil and gas
Jim Wells....	Bandera	Magnolia Petr. Co. Garcia No. 1	8,302	Yegua	Gas
Kleburg......	Wildcat	Superior Oil Co. Koch No. 1	7,522	Frio	Dry
Kelburg......	Wildcat	Magnolia Petr. Co. Dietz No. 1	7,500	Frio	Dry
Kelburg......	Bird Island (Discovery)	Pure Oil Co. State No. 1	9,636	Frio	Gas
Nueces.......	North Agua Dulce (Discovery)	Union Producing Co. Simmons No. 1	8,706	Vicksburg	Oil and gas
Nueces.......	Agua Dulce	Union Producing Co. Galladay No. 1	8,190	Vicksburg	Oil and gas
Nueces.......	Agua Dulce	Union Producing Co. Torbett No. 1	7,700	Vicksburg	Oil
Nueces.......	Luby	Seaboard Oil Co. Luby No. 7	7,595	Frio	Dry
Nueces.......	Saxet	Richardson Petr. Co. Erigan No. 2	7,999	Frio	Oil and gas
Nueces.......	Wildcat (Submerged)	Coastline Oil Co. State No. 1	8,660	Frio	Dry
Nueces.......	Wildcat	Seaboard Oil Co. Lockett No. 1	7,510	Frio	Dry
Nueces.......	Saxet	Conroe Oil Co. Bliss No. 10	7,505	Frio	Oil
Nueces.......	Turkey Creek	Carlos Oil Co. Smith No. 1	7,511	Frio	Oil
Nueces.......	Saxet	Richardson Petr. Co. Cain & Sechrist No. 24	9,927	Frio	Oil
Nueces.......	Wildcat	Phillips Petr. Co. Mastin No. 1	7,765	Frio	Dry
Nueces.......	Wildcat	The Texas Company Little No. 1	7,751	Frio	Dry
Nueces.......	Agua Dulce	Union Producing Co. Minnie Brown No. 1	13,728	Cockfield	Testing
Willacy......	Wildcat	Magnolia Petr. Co. Armendiaz No. 1	10,325	Frio	Dry
Willacy......	Wildcat	Salvieda Oil Co. Garcia Land No. 2	10,007	Frio	Dry
LAREDO DISTRICT, WELLS DRILLED TO 6,000 FEET AND BELOW					
Duval........	Benavides	F. Gravis Vaello No. 1-A	6,018	Yegua	Oil and gas
Duval........	Wildcat	Southwood Oil Co. Nolen No. 1	6,258	Yegua	Dry
Duval........	Wildcat	Magnolia Petr. Co. Lopez No. 1	6,950	Yegua	Dry
Duval........	Wildcat	Magnolia Petr. Co. Hoffman No. 1	6,627	Yegua	Dry
Duval........	Sweden	Hiawatha Oil Co. Herberger No. 5	6,109	Yegua	Dry
Duval........	Wildcat	Standard of Texas D. Garcia No. 1	7,095	Yegua	Dry
Duval........	Wildcat	Corpus Christi & Taylor Ref. Co. Parr No. 1	6,060	Yegua	Dry
Duval........	Benavides	Hiawatha Oil Co. Southland No. 11	6,510	Yegua	Dry
Duval........	Benavides	Mid-Continent Petr. Co. Rodriguez No. 1	6,155	Yegua	Dry
Duval........	Benavides	Hiawatha Oil Co. Southland No. 12	6,200	Yegua	Dry
Jim Hogg.....	Wildcat	Humble Oil & Ref. Co. K. Bass No. 1	7,017	Jackson	Dry
Jim Hogg.....	Wildcat	Goldston & Fox Canales No. 1	6,017	Vicksburg	Dry
Starr.........	Wildcat	J. S. Collins A. Guerra No. 1	7,009	Vicksburg	Dry
Starr.........	Rincon (Discovery)	Transwestern Oil Co. Slick School No. 1	6,862	Jackson	Gas
Starr.........	Wildcat	Collins & Co. F. B. Guerra No. 1	6,609	Vicksburg	Dry
Starr.........	La Reforma (Discovery)	Wheelock & Collins F. B. Guerra No. 1-A	7,010	Vicksburg	Oil and gas
Starr.........	Wildcat	Sun Oil Co. Spear No. 1	6,113	Vicksburg	Dry

TABLE 4.—*Total Number of Wells Drilled in South Texas during* 1938

LAREDO DISTRICT

Field	Oilers[1]	Gassers	Dry Holes
Duval County			
Benavides	122	6	12
Casa Blanca	24	5	4
Cedro Hill	1	0	0
Charamousca	4	0	3
Cole Bruni	0	0	1
Cole (Gas)	0	0	1
Colmena	2	0	0
Conoco Driscoll	10	0	1
Eagle Hill	29	2	4
Fitzsimmons	39	0	4
Government Wells	6	0	2
Hoffman	130	4	8
Labbe	1	1	6
Longhorn	1	0	0
Los Picachos	1	0	1
Lundell	27	1	0
Palangana	0	0	1
Peters	0	2	2
Piedre Lumbre	15	0	1
Pietras Pintas	0	0	1
Rancho Solo	9	0	2
Sarnosa	1	0	1
Seven Sisters	4	0	0
South Seven Sisters	30	0	9
Sweden	2	1	1
Tesoro	4	0	4
Total	462	22	69
Jim Hogg County			
Alworth	1	0	1
Colorado	3	0	0
Kelsey	2	0	2
Las Animas	3	1	1
Total	9	1	4
McMullen County			
Calliham	5	0	2
Campana	1	0	0
Ezzell[2]	24	1	8
Jacob	2	0	1
Loma Alta	2	0	1
Munson	8	2	3
Rhode	0	3	0
San Jose	1	1	1
South Calliham	3	0	0
Total	46	7	16
Starr County			
Barbacoas	0	0	1
North Barbacoas	2	0	3
El Tanque	3	1	3
La Reforma[3]	2	0	0
Ricaby	2	0	0
Rincon[3]	1	0	0
Sacatosa	0	1	2
Santo Domingo	0	1	0
Sam Fordyce	4	1	0
North Sam Fordyce	5	0	0
Sun	4	0	0
Young	0	1	0
Total	23	5	9
Webb County			
Aviator	0	0	1
Carolina-Texas	0	0	1
Cole (Gas)	0	0	1
Cole Bruni	4	2	3
Cole O'Hern	5	1	2
Houser[3]	1	0	0
Killam	18	1	5
North Killam	1	0	0
Loma Valdez	0	1	0
Lopez	0	0	1
Oilton	63	2	11
Total	92	7	25

Laredo District continued at foot of next column.

SOUTH CORPUS CHRISTI DISTRICT

Field	Oilers[1]	Gassers	Dry Holes
Brooks County			
Alta Mesa	8	0	2
Alta Verde	1	0	5
Kelsey	1	0	0
Total	10	0	7
Hidalgo County			
La Blanca	1	0	0
McAllen[3]	2	0	0
Mercedes	3	0	0
Sam Fordyce	29	1	2
San Salvador[3]	1	0	0
Weslaco[3]	1	0	0
Total	37	1	2
Jim Wells County			
Alice	55	8	8
Alfred	3	0	5
Armagosa	0	1	0
Bandera	0	2	0
East Premont	4	0	0
Premont	4	2	2
Sandia	0	0	1
Total	66	13	16
Kleburg County			
Bird Island	0	1	0
Kingsville	0	0	1
Total	0	1	1
Nueces County			
Agua Dulce	6	2	3
Agua Dulce (North)[3]	2	0	0
Baldwin	0	0	1
Chapman	0	0	1
Clara Driscoll	24	0	1
Clara Driscoll (South)	12	1	0
Corpus Christi	3	1	1
Flour Bluff	14	0	7
Luby	84	0	5
Richard King	8	2	0
Riverside	0	2[4]	0
Saxet	66	6	13
Stratton	4	0	0
Sullivan	1	0	0
Turkey Creek	52	1	13
Total	276	15	45
San Patricio County			
Aransas Pass[5]	13	0	0
East Plymouth	0	1	1
East White Point	30	0	1
Midway	4	0	0
Plymouth	19	0	1
Taft	3	1	1
White Point	1	0	0
Total	70	2	4
Grand total, South Corpus Christi District	459	32	75

LAREDO DISTRICT (CONTINUED)

Field	Oilers[1]	Gassers	Dry Holes
Zapata County			
Andrews	0	1	1
Charco Redondo	0	0	3
Comitas	12	0	5
Escobas	28	0	9
Mirando Valley	10	1	2
Total	50	2	20
Grand total, Laredo District	682	44	143

[1] Gas and distillate wells listed under oilers.
[2] There were also 21 oil wells and 5 dry holes completed in the Live Oak County portion of Ezzell field.
[3] New gas and distillate field. [4] One crater.
[5] There were also 39 oilers and 3 dry holes completed in the Aransas County portion of the Aransas Pass field.

This field was extended into Brooks County by Humble Oil & Refining Company's McGill No. 1, 4664 ft. east of production, when it was completed for a flow of 216 bbl. of oil per day from sand at 4697 to 4718 ft. Pressures were 750 lb. on tubing and 1100 lb. on casing, through $\frac{3}{16}$-in. choke.

Extensions to Established Areas

Colorado Field.—The Colorado field, southwestern Jim Hogg County, was given a north extension through the completion of K. D. Harrison et al.'s F. G. Martinez No. 1, sec. 623, for a flow of 60 bbl. of 46° gravity oil per day through open tubing from Cockfield sand at 3006 to 3015 ft. Pressures were 20 lb. on tubing and 145 lb. on casing, which was set at 3003 feet.

TABLE 5.—*Rank Wildcats (Discoveries) Completed during* 1938

County	Oil	Distillate and Gas	Gas	Dry Holes
LAREDO DISTRICT				
Duval	6	0	0	63
Jim Hogg	1	0	0	6
McMullen	3	0	0	46
Starr	2	2	2	22
Webb	1	1	1	42
Zapata	0	0	0	11
Total	13	3	3	190
SOUTH CORPUS CHRISTI DISTRICT				
Brooks	0	0	0	4
Cameron	0	0	0	0
Hidalgo	0	3	0	3
Jim Wells	2	1[1]	1	18
Kenedy	0	0	0	0
Kleburg	0	0	1	2
Nueces	1	1	1	14
San Patricio	1	0	1	10
Willacy	0	0	0	2
Total	4	5	4	53
Grand total	17	8	7	243

[1] Co-discovery for Alice oil field.

McMullen County

San Jose Field.—The San Jose field was discovered on Aug. 2 through the completion of V. G. Schimmel et al.'s L. Kountz Estate No. 2, which flowed an estimated 3,000,000 cu. ft. of gas and 5 bbl. of 23° gravity oil per day, through perforations at 1159½ to 1163 ft. in Cole sand found at 1147 to 1163 ft. Production was through ¼-in. choke, under 245 lb. tubing pressure and 295 lb. casing pressure. Total depth was 2012 ft. After plugging back, casing was set at 1280 ft. This well had oil showings in the Government Wells zone at 1791 to 1795 ft. and 1812 to 1828 ft., but both sands tested salt water. Since the Cole sand also contained oil shows, there seems to be a possibility of multiple-sand oil production elsewhere along this shore line.

Munson Field.—On Aug. 31, the Munson field, in the extreme southwest corner of McMullen County, was opened by Bruce Albrights' Nueces Land and Live Stock Company No. 1, which was completed as a pumper producing 80 bbl. of 22° gravity oil per day from Mirando sand at 1201 to 1213 ft. Total depth was at 1213 ft. and perforations were made at 1201 to 1211 ft. in casing set on bottom. This field is several miles updip from the Charamousca field, in northern Duval County, and produces from the same sand.

Campana Field.—William H. Spice, Jr., et al. discovered the Campana field on Sept. 21 through the completion of the H. C. Edrington Estate No. 1 well, sec, 57, in Upper Government Wells sand at 2492 to 2517 ft. Flow of 20 bbl. of 22° gravity oil per day, along with 500,000 cu. ft. of gas, was through ¼-in. choke on 2-in. tubing. Total depth was 2519 ft. This well topped the Jackson at 1870 ft. and the Hockleyensis at 2206 ft. The lower part of the producing sand carried oil saturation while the upper portion showed gas. This field is on a trend with the Government Wells and Seven Sisters fields in Duval County.

Extensions to Established Areas

Ezzell Field.—Edwin M. Jones' Ezzell No. E-1 was completed in January as a 2800-ft. southwest extension to the Ezzell field, when it flowed 150 bbl. of oil daily from the regular Loma Novia sand at 1524 to 1530 ft. Jones' Ezzell No. F-1, 4800 ft. southwest of production, provided another extension to this field during the same month when it was completed flowing 525 bbl. of oil daily from sand at 1527 ft. In September, this field received a 6000-ft. southwest extension when Harry Ezzell completed his Fee No. 22 from sand at 1506 to 1519 ft. Flow of 396 bbl. of oil on a 12-hr. gauge was through perforations at 1507 to 1517 ft.; production was through open tubing under pressures of 75 lb. on tubing and 385 lb. on casing. In October, the field was given still another southwest extension by Jones' Ezzell No. 40, which was completed as a pumper pro-

ducing 150 bbl. of oil per day from sand at 1526 to 1534 ft. This well was one mile from nearest production.

Loma Alta Field.—The Loma Alta field received a 1¼-mile northeast extension through the completion of W. A. Wagner's (Alabama Minerals) M. Gordon No. 3, sec. 127, which pumped 40 bbl. of 21.7° gravity oil a day from a new sand (Government Wells) at 2221 to 2232 ft. This sand was found approximately 60 ft. below the regular Chernosky sand, which produces in the Loma Alta field. This has been classified by some as a new and separate field, but general opinion is that it is another sand lens on the same structure.

Rhode Gas Field.—The Rhode gas field was extended ½ mile south by Loma Oil Company's H. C. Edrington No. 1, which showed a flow of 23,300,000 cu. ft. of gas under 600 lb. rock pressure from Cole sand at 1800 to 1820 feet.

Starr County

Rincon Field.—On Feb. 21, Transwestern Oil Company's Slick Shool No. 1, in sec. 266, opened the Rincon field from Vicksburg sand at 4172 to 4259 ft., through perforations at 4212 to 4230 ft. Flow of 5,000,000 cu. ft. of gas and 1 bbl. of 59° gravity distillate per day was through ¼-in. choke under pressures of 1700 lb. on tubing and 1700 lb. on casing. This area is on the T. B. Slick Estate Ranch in east central Starr County and is 16 miles north of the Sam Fordyce field. This well found the Frio at 1945 ft. and topped the Vicksburg at 3951 ft. The Rincon structure is an anticline, of which the axis lies in a north and south direction. No faulting was disclosed through correlations with three deep wells previously drilled within ½-mile radius of the discovery well. The sand producing in this well showed a fair saturation with distillate; its porosity ranged from 26 to 39 per cent and its probable average thickness is 40 feet.

Young Field (*Charco Blanco*).—The Young field, 14 miles north of Rio Grande City, and in Porcian 79, was opened on June 14 by Sun Oil Company's Mrs. J. J. Young No. 1, which flowed an estimated 3,000,000 cu. ft. of dry gas per day through 3/16-in. choke under pressures of 960 lb. on tubing and 1000 lb. on casing. Production was from Jackson sand at 2708 ft. to 2730 ft. *Hockleyensis* was topped at approximately 2100 ft. Other sands were found in this well, at 1279 to 1307 ft., 1840 to 1844 ft. (perforations), 2078 to 2085 ft. and 2208 to 2214 ft., and though all carried salt water, there is a possibility that they may produce oil or gas elsewhere on this structure, about which little is known.

La Reforma Field.—Wheelock and Collins' F. B. Guerra No. 1-A, the company's third test on the La Reforma prospect, was completed on July 23, in basal Frio sand at 5917 to 5969 ft., flowing 2,500,000 cu. ft. of gas and 60 bbl. of 51.6° gravity, straw-colored distillate per day to

open the La Reforma field. Production was through 3/16-in. choke with 2125 lb. pressure on tubing and 2300 lb. pressure on casing. Gas-oil ratio was approximately 40,000 to 1. Total depth was at 7010 ft. Completion was effected in the Frio after several Vicksburg sands below 6000 ft. tested salt water. The company's first well on this structure, A. Guerra No. 1, was abandoned at 7009 ft., although oil and gas shows were found in Frio and Vicksburg between 5850 and 6300 ft. Rig was then moved 3000 ft. west and 1500 ft. south for F. B. Guerra No. 1, which blew out at 6609 ft. and ran wild, finally being killed and junked. The Vicksburg, in this well, was topped at 6059 ft. Rig was then moved 200 ft. south, where discovery was completed.

The La Reforma structure, an anticlinal fold covering several thousand acres, will probably trend in a slightly northwest and southeast direction, and although development has been rather disappointing to date, it has possibilities of becoming an important multiple-sand producing area. There are indications of faulting; the discovery well apparently cut a fault, as the log of the lower portion of the hole was considerably at variance with loggings of the two failures.

Sun Field.—More than 12 miles south of the Kelsey field, and on the same Kelsey anticline, the Sun field was discovered by Sun Oil Company's Mrs. A. McKinney No. 1, sec. 242, northern Starr County. This well, completed on Sept. 15, flowed 180 bbl. of 43.7° gravity oil per day through 5/32-in. choke, with tubing pressure at 730 lb. and casing pressure at 990 lb.; gas-oil ratio was 640:1. Perforations were made at 4853½ to 4856½ ft. in Frio sand logged at 4842 to 4858 ft. The sand in both this well and the discovery well of the Kelsey field, Jim Hogg County, was found at the approximate contact of the Frio and Vicksburg zones.

Second Sand.—Sun Oil Company's Olivarez et al. No. 1, sec. 239, was completed in November for a flow of 132 bbl. of oil per day from perforations at 4905 to 4910 ft. in basal Frio sand at 4901 to 4911 ft. Production was obtained through 5/32-in. choke under pressures of 450 lb. on tubing and 1250 lb. on casing. Total depth was at 5709 ft., in the Vicksburg.

Third Sand.—In December, Circle Oil Company's S. Olivarez No. 1 was completed in a new sand found in the Vicksburg at 5115½ to 5135 ft. through perforations at 5117 to 5119 ft. This well flowed 55 bbl. of 47.9° gravity oil per day through ⅛-in. choke, under 2000 lb. tubing pressure and 1325 lb. casing pressure.

Sacatosa Field.—The Sacatosa field was discovered on Oct. 5 by Harvey and Henderson and Hagan and Stewart's Zaragosa and José A. Salinas No. 2, which was completed in Government Wells sand at 1650 to 1661 ft., through perforations at 1657 to 1661 ft., for an estimated flow of 5,000,000 to 6,000,000 cu. ft. of dry gas per day. Flow was through ¼-in. choke and under tubing pressure of 400 lb. Total depth was

1705½ ft.; top of Cole was found at 810 ft., while Government Wells zone was topped at 1650 ft. This field, whose production is from a stratigraphic trap caused by a pinch-out in the Government Wells sand, is on a regional nose that dips toward the northeast through the Guerra (Cuevitas) field, 5½ miles distant.

North Barbacoas Field.—In May, Lee Davis' M. M. Garcia No. 1, in sec. 956, and 3 miles north of Barbacoas field, flowed 100 bbl. of fluid, mostly oil, from perforations in Frio sand at 2663 to 2669 ft. This was considered an extension to Barbacoas rather than a new field, but an attempt to connect these two areas ended in failure when Henshaw Brothers and Eastern Oil Company's Stalley No. 1, midway between the two producing areas, was abandoned in salt-water sand topped at 2740 feet.

New Sands in Existing Fields

Sam Fordyce Field.—A new Frio sand in the northwestern portion of Sam Fordyce field was found in March by H. J. Porters' A. Flores No. 3 at 3183 to 3196 ft. The well drilled to 3365 ft., plugged back to 3206 ft., and when perforated at 3183 to 3189 ft. flowed 15 million cubic feet of gas daily.

Extensions to Established Areas

Santo Domingo.—In April, John H. Clopton No. 5 Roos and Bennett, in the Santo Domingo gas field, was completed as a gasser from sand at 2498 ft. to extend the field 1000 ft. to the south in the regular Frio sand.

Webb County

Lome Valdez Field.—On Jan. 1, Howard Nessley's A. M. Bruni No. 3 opened a new Cole sand field, 8 miles south of Bruni in southeastern Webb County, when it was completed producing 7,000,000 cu. ft. of gas per day through ⅜-in. choke, from sand at 1790 to 1812 ft. Perforations were made at 1804 to 1808 ft., where the best oil show was found, but no oil was produced on tests. The well showed 400 lb. working pressure and 450 lb. closed-in pressure. Cores showed gas sand from 1790 to 1804 ft., oil and gas sand at 1804 to 1812 ft., and shale and sand streaks to total depth at 1850 ft., where casing was set. This structure, sand lenses on a nose, dips to the east and, as mapped, is about 4 miles long and 1 to 1½ miles wide. Oil shows point to the possibility of future oil production for this area; however, the Cole sand lenses out ¼ to ½ mile to the west of the discovery well.

Houser Field.—The Houser field, 3 miles north of the Oilton field and 1 mile northwest of the Killam field, was discovered by W. F. Houser et al.'s F. G. Garcia and C. D. Villareal No. 1, sec. 720, when it was completed as a gasser flowing an estimated 15,000,000 cu. ft. of gas and

spraying several barrels of 45° to 46° gravity oil per day. Flow was through perforations at 2492½ to 2496½ ft. in Rosenburg sand found at 2492 to 2524 ft., and was through ¼-in. choke. Casing was set at total depth of 2524 ft.; the well showed a working pressure of 800 lb. and shut-in pressure of 1100 lb. The producing sand, broken by numerous shale streaks, carried a high gas content and contained a slight odor of high-gravity oil. This well also found Mirando sand at 1992 to 1995 ft. and at 2006 to 2017 ft.; a test between 1970 and 2013 ft. recovered 420 lb. working pressure and no oil. This field is similar to other rather limited fields in its immediate vicinity in that its production is controlled by sand lenses along a shore line or monocline. It is on trend with the Killam-Oilton structures and also with the outpost gasser, the Moore and Meaders No. 1 Garcia and Villareal, which last year discovered Rosenburg (Cockfield) sand production 1½ miles north of Oilton.

North Killam Field.—Dovre, Brown and Taylor Refining Company's Guerra (Zapata) No. 1, one mile north of the Killam field, was completed for a flow of about 100 bbl. of 22° gravity oil to discover the North Killam field in December. Production was obtained from perforations at 2046 to 2051½ feet in Mirando sand found at 2045 to 2051½ feet.

New Sands in Existing Fields

Cole Bruni Field.—In March, Kenyon Oil Company's No. 1 Benavides, in the south end of the Bruni field, was completed through perforations at 3270 to 3280 ft., in a new Yegua sand, for a flow of 136 bbl. of 36.2° gravity oil per day through 3/16-in. choke, under 900 lb. working pressure. This well found the regular Bruni sand at 3419 to 3444 ft.; after testing salt water at this level, it was plugged back to 3290 ft., where completion was made in the new sand.

Oilton Field.—In the Oilton district, O. W. Killam and Campbell's E. M. Thompson (Wher) No. 5 was completed in the Rosenburg (Cockfield) sand at 2473 to 2482 ft. as the first well in the main field to be drilled to this lower level. This horizon was discovered last year by a gasser 1½ miles north of the field; another well, on the west side of the field, showed a little oil in this sand but commercial production was not obtained. The Thompson No. 5 well was also soon abandoned after producing several barrels of oil per day from this zone.

Extensions to Established Areas

The Killam and Oilton fields were merged into one producing area in January by the completion of L. H. Jones' F. O. Saenz No. 1, block 6, sec. 1005, Webb County, midway between the two areas, when it was completed flowing 275 bbl. of oil daily from Mirando sand at 1921 to 1927 feet.

Zapata County

New Sands in Existing Fields

Mirando Valley Field.—The most important development of the year in Zapata County was the opening of a new sand, on Feb. 24, in the first commercial oil-producing field discovered in South Texas, the Mirando Valley field. The discovery well, Burt Calvin's Rufino Lopez No. 1, just east of production, was completed heading 300 bbl. of 23° gravity oil per day, under 35 lb. pressure, from an oil sand cored in the Cockfield zone at 1873 to 1881 ft. The regular field production is from the *Hockleyensis* at approximately 1425 feet.

SOUTH CORPUS CHRISTI DISTRICT

Hidalgo County

Weslaco Field.—On Feb. 6, the Weslaco field, 2 miles southwest of Weslaco, was brought in through the completion of Atlantic Refining Corporation's American Rio Grande Land and Irrigation Company No. 1, sec. 175. This well was drilled to 9182 ft.; completion was first effected in Frio sand through perforations at 8990 to 9005 ft. where a flow of 19 bbl. of 48.6° gravity amber distillate per day was obtained through ⅜-in. choke, under 1000 lb. tubing pressure and 1225 lb. casing pressure. Previous perforations had given the following results: at 9148 to 9155 ft., dry; at 9008 to 9015 ft., slight amount of gas; at 8985 to 9000 ft., gas and distillate. The well was then reworked and perforated at 8810 to 8820 ft., where it showed gas. When another set of perforations at 8800 to 8808 ft. also showed gas, the well was plugged back to 8782 ft. where a flow of 74.5 bbl. of 51.5 white distillate, 7,500,000 cu. ft. of gas, and 8 bbl. of sweet water per day resulted from perforations at 8634 to 8642 ft. Flow was through ⅜-in. choke with pressures of 2950 lb. on tubing and 3100 lb. on casing. These zones, mostly hard distillate sands of minor saturation, are on a rather large anticline, whose axis strikes to the north and south. In this well, Catahoula was topped at 4290 ft., Fossil zone at 5010 ft. and Frio at 5662 feet.

San Salvador Field.—The San Salvador field, 2 miles northwest of the Mestenas field, was discovered during the latter part of April by Gulf States' Cardenas No. 1, which flowed 110 bbl. of 55° gravity clear distillate and 5,800,000 cu. ft. of gas per day through 5⁄16-in. choke from perforations at 7630 to 7640 ft. in Frio sand. Tubing pressure was 3200 lb. and casing pressure was 3300 lb. At total depth of 8003 ft. the well was still in the Frio zone. This discovery has been classified by some as a 2-mile northwest extension to the Mestenas field.

McAllen Field.—R. E. Harding and Pantano Oil Corporation's W. W. Woody No. 1, Porcian 69, produced 24 bbl. of 61.5° gravity distil-

late and 2,500,000 cu. ft. of gas per day from perforations at 5970 to 5974 ft. in Frio sand at 5970 to 5994 ft., to discover the McAllen field, 2 miles southeast of McAllen, on Aug. 19. Flow was through 3/8-in. choke; pressures were 2025 lb. on tubing and 2050 lb. on casing. Total depth of this well was 7214 ft.; estimated top of the Fossil zone is at 4012 ft. and top of Frio at 4408 ft. This structure, an elongated dome, is considered to be a very deep-seated salt dome; this field should be large from an acreage standpoint, although production probably will be mostly distillate with high gas ratio. The producing sand was rather hard and very gassy.

This field was given an extension and two new sands by R. E. Harding's E. M. Card No. 1, 1/2 mile east of the McAllen city limits, when it flowed 180 bbl. of 55° gravity white distillate and 5,500,000 cu. ft. of gas daily through 3/8-in. choke from perforations at 7440 to 7465 ft. in Vicksburg sand at 7402 to 7498 ft. Pressures were 1750 lb. on tubing with casing sealed. Total depth was 7507 ft. After flowing for a few days, the well was plugged back and showed for a gas and distillate producer at 6920 to 6955 ft. Final completion was still pending at the end of the year, after a test of the regular sand.

New Sands in Existing Fields

Mercedes Field.—Union Sulphur Company's American Rio Grande Land and Irrigation Company No. 1, the deepest test in the Mercedes field, was drilled to 9618 ft.; after perforation and testing of several new distillate and gas sands between 7900 and 9000 ft., this well was completed flowing 35 bbl. of 61° gravity distillate and 3,000,000 cu. ft. of gas daily from perforations in the regular Frio zone at 7430 to 7440 ft. Flow was through 3/8-in. choke, under 1100 lb. tubing pressure and 1300 lb. casing pressure.

Sam Fordyce Field.—A new sand, in the Jackson, was opened in December in the Sam Fordyce field by Phillips Petroleum Company's Flores No. 1, deepest test in the field. After drilling to 9708 ft., this well was plugged back to 5950 ft. and perforations were made at 5840 to 5900 feet, where 50 bbl. of white distillate and 2,260,000 cu. ft. of gas were obtained daily through 3/16-in. choke, under 2800 lb. working pressure.

Extensions to Established Areas

Sam Fordyce Field.—H. C. Dean's Sheldon No. 1, between the Sam Fordyce and North Sam Fordyce fields, was completed through perforations at 2835 to 2839 ft. in Frio sand to provide a 1600-ft. extension to this field in October. Flow of 10 bbl. of fluid hourly was through 1/8-in. choke and under pressures of 200 lb. on tubing and 700 lb. on casing. This well found gas sand at 1780 to 1805 ft., oil sands at 2700 to 2768 ft.,

2835 to 2839 ft., 2857 to 2865 ft., and oil and salt-water sand at 2925 to 2960 ft. Total depth was 3015 ft. with casing set at 2990 feet.

Kleburg County

Bird Island Field.—Pure and Superior Oil Companies' State of Texas No. 1 was completed on Nov. 28, as the first wildcat producer in submerged lands of South Texas, to discover the Bird Island field. This well, in tract 522 on Bird Island, in Laguna Madre, Kleburg County, was completed in sands logged at 7200 to 7310 ft. for a flow of 75,000,000 cu. ft. of gas per day under 2700 lb. pressure. Production was obtained through a series of perforations at 7210 to 7230 ft., 7239 to 7256 ft., and 7269 to 7278 ft. Perforations at 7290 to 7310 ft. showed gas and salt water.

A canal approximately 15 miles long was dredged through Laguna Madre to provide transportation of supplies and equipment to the well location by means of barges.

This structure, probably a faulted anticline, is expected to cover a large area. The discovery well topped Small *Discorbis* at 6028 ft., *Eponides* at 6120 ft., Large *Discorbis* at 6688 ft., *Heterostegina* at 6844 to 6864 ft., Round *Marginulina* at 7090 ft., and Flat *Marginulina* at 7195 feet.

Jim Wells County

Alfred Field.—Rowan and Hope's Robert Adams No. 1, 1½ miles northwest of Alfred and 10 miles northeast of Alice, was completed on Feb. 24 to discover the Alfred field from a Frio sand at 3223 to 3234 ft. Initial production of 125 bbl. of oil daily was from perforations at 3224 to 3229 ft., through 5⁄32-in. choke, with tubing pressure of 125 lb. and casing pressure of 340 lb. Total depth was 5509 ft. The *Discorbis* was topped at 2595 ft., the Vicksburg at 4725 ft. and the Jackson at 5375 ft. Other sands indicated by Schlumberger as having possibilities were at 3330 to 3340 ft.; 4205 to 4210 ft., 4925 to 4930 ft. (Vicksburg) and at 4995 to 5010 ft. (Vicksburg). This well was drilled on trend with several failures on the Alfred prospect, most of which carried oil and gas shows. The lower sands found in these wells do not indicate very much structure, and production in the upper sand is probably controlled by sand lensing. The sand in this well showed a saturation of 2 to 3 per cent, and a porosity of 28 to 33 per cent.

Alice Field.—On April 15, Presnall and Mosser's Mortgage Investment Company No. 1, 2½ miles southwest of Alice, was completed on the Alice prospect from Frio sand at 3480 to 3496 ft., producing 2,800,000 cu. ft. of gas and 4 bbl. of distillate per day through 3⁄16-in. choke from perforations at 3491 to 3494 ft. Pressures were 1350 lb. on tubing and 1400 lb. on casing; closed-in pressure was 1500 lb. Cores from 3480 to

3486 ft. showed only gas and from 3486 to 3496 ft., total depth, oil and gas were present. This well found the *Discorbis* at 2840 ft. and Frio at 3040 to 3050 feet.

SECOND SAND.—On April 18, and 5 miles south of Alice, H. H. Howell brought in his No. 1 Reed and Lindsay from Vicksburg sand at 5375 to 5425 ft., to discover commercial oil production on this structure and to focus interest on the possibilities of the Vicksburg trend. From 5375 to 5400 ft., the sand carried good oil odor and from 5400 to 5425 ft. a good oil show was present but salt water was also indicated. Casing was set at total depth of 5430 ft. and perforated at 5375 to 5385 ft. where a production of 177 bbl. of oil per day through ⅛-in. choke was obtained under 900 lb. tubing pressure and 1085 lb. casing pressure.

These two wells, discovered almost simultaneously, are considered to be part of the same field, lying on the same anticlinal structure, which shows two individual highs and is about 6 or 7 miles long, trending northeast and southwest just south of Alice. Faulting to the west and southeast of the structure is indicated. The Howell well topped Fossils at 2778 to 2810 ft.; Frio at 3042 to 3073 ft., First Shells (probable top of Vicksburg) at 5197 to 5228 ft. and *Ammobaculites* at 5400 to 5418 ft. Howell had previously drilled two wells 2½ miles southeast; although both showed oil and gas on tests, neither ranked as a commercial producer.

THIRD SAND.—A second level in the Frio was proved productive in Alice by Tom Graham's Charles Martens No. 1, 5 miles southwest of the Pressnall and Mosser well and 2 miles west of the Howell well. This well flowed gas on completion from sand at 3522 to 3533½ ft. but later produced oil. These two completions in the Frio proved a 5-mile trend in the 3500-ft. level.

FOURTH SAND.—Another level in the Frio was proved productive in May by W. J. Goldston's Lindsay and Reed No. 1, which came in as a gasser spraying 45° oil through perforations at 5155 to 5160 ft. in sand at 5141 to 5161 ft. Flow was through 3/16-in. choke and under pressures of 1900 lb. on tubing and 2125 lb. on casing. This well found salt water in the discovery sand.

FIFTH SAND.—H. H. Howell opened the 4700-ft. sand, previously logged by several wells, with his H. J. Mosser No. 1, which was completed in August for a flow of 160 bbl. of oil per day from perforations at 4788 to 4799 ft. through 3/16-in. choke. Pressures were 750 lb. on tubing and 1400 lb. on casing. This well, which also extended the field 2 miles southwest, tried to blow out from a sand found at 7190 to 7260 ft. Total depth was 7335 feet.

SIXTH SAND.—A second level in the Vicksburg was opened in October by Southern Mineral Corporation's Stillwell No. 1, block 17, on the west side of the field, at 5425 to 5452 ft., where completion was effected through perforations at 5441 to 5451 ft. for a flow of 600 bbl. of oil daily.

Seventh Sand.—After finding salt water in the 5300-ft. zone, R. B. Bryant's Rattan No. 2, block 13, was completed in a new Frio sand through perforations at 5031 to 5037 ft. for a flow of 100 bbl. of oil on a 12-hr. gauge. Production was through $\frac{3}{16}$-in. choke, under 75 lb. tubing pressure and 750 lb. casing pressure. This sand was previously found by a number of wells but owing to offsetting obligations no former completions were made at this level.

Eighth Sand.—The 5200-ft. sand in Alice field, also logged by several wells in this field, was established as a producer during the first part of November by Texas Gulf Producing Company's Smith and Gardner No. 2, which flowed oil through perforations at 5211 to 5223 ft. This well was drilled to 5618 ft. after missing the 5400-ft. sand.

Other Data.—This field's deep Vicksburg production was given a 2-mile northeast extension in December by Graham and Mosser's Bankers Mortgage Company No. 1, which flowed 60 bbl. of fluid per day from perforations at 5329 to 5333 ft. in sand at 5286 to 5339 feet. Developments in this field indicate an elongated domal type of structure with sands dipping steeply off the axis in all directions, especially to the southwest. Several wells on top of the structure have produced much gas.

Bandera Field.—The Bandera field, on La Anima Sola prospect, in southwestern Jim Wells County and near the Duval County line, was discovered by Magnolia Petroleum Co. on Aug. 2 when its Paula G. de Valades No. 1 was completed for a flow of an estimated 40,000,000 cu. ft. of dry gas per day from Jackson sand at 6408 to 6415½ ft. Flow was through 2-in. tubing; shut-in pressures were 3550 lb. on tubing and 3635 lb. on casing. Total depth was at 6419 ft. and casing was set at 6408 ft. The well had previously blown out and stuck drill pipe at the discovery level, causing a long fishing job. This structure, on the Vicksburg trend, is considered to be a large local faulted anticline trending northeast and southwest through Jim Wells County, upon which the Alice field is located. It is believed that future developments in this field will establish oil production of the flanks of this structure.

New Sands in Existing Fields

East Premont Field.—Transwestern Oil Company's Dunlap No. 1, 6000 ft. southwest of East Premont production, was completed in November for a flow of 2 bbl. of 60° gravity distillate per hour from perforations at 5365 to 5370 ft. in Frio sand. Production was through ¼-in. choke under 2000 lb. tubing pressure and 1975 lb. casing pressure. This well had been drilled to 6766 ft. after finding Vicksburg sand at 6680 to 6690 ft. hard and carrying only an odor.

After showing for a distillate producer through perforations in the regular 6600-ft. sand, and also at 6132 to 6138 ft. and 5807 to 5812 ft. in new Frio sands, Magnolia Petroleum Company's A. A. Seeligson No.

10 was completed in December in a Frio sand through perforations at 5626 to 5632 ft. for a flow of 85.16 bbl. of oil per day through 3/8-in. choke under 1975 lb. tubing pressure and 2125 lb. casing pressure.

Nueces County

Turkey Creek Field.—On Jan. 4, the Turkey Creek (West Saxet) field was discovered by L. A. Douglas' Charles McKenzie No. 1, approximately 5000 ft. west of a major fault of at least 500 ft. displacement, and on its upthrow side. This well produced 571 bbl. of 35.2° gravity oil per day through 1/4-in. choke under pressures of 1400 lb. on tubing and 1600 lb. on casing, through perforations at 5810 to 5812 ft. in Frio sand at 5794 to 5813 ft., total depth of well and casing. *Discorbis* was topped at 4159 ft., *Heterostegina* at 4323 ft. and Frio at 4515 ft. This Frio sand showed a porosity of 28 per cent, and a saturation of 4.5 per cent. The field was given a rapid development until failures in all directions limited outpost operations.

Second Sand.—In March, a Frio sand at 5641 to 5660 ft. was found by Rand Morgan's Fee No. 1, which flowed 10 bbl. of oil per hour through 5/32-in. choke under 875 lb. tubing pressure and 1105 lb. casing pressure. This well found the discovery sand very thin and carrying salt water.

Third Sand.—A shallow sand in the Catahoula was found in April by Rand Morgan, when an electric log indicated a sand at 3846 to 3860 ft., in his Fee No. 2-C well, which had drilled to 5975 ft. after missing both the 5600-ft. and 5800-ft. sands. When perforated at 3846½ to 3850 ft., this sand produced a daily flow of 125 bbl. of oil through 11/64-in. choke, under 550 lb. tubing pressure and 950 lb. casing pressure.

Fourth Sand.—A fourth and deeper Frio sand for this field was opened in May by Renwar Oil Company's Mrs. M. S. T. Kenedy No. 2-B, which cored gas, distillate and oil sands at 6430 to 6456 ft. On completion this well flowed 50 bbl. of 28° gravity oil on an 8-hr. test through 5/32-in. choke. Pressures were 780 lb. on tubing and 1150 lb. on casing.

Fifth Sand.—Another level in the Catahoula was proved productive in September by Carlos Oil Company's F. J. Smith No. 1, sec. 420, when it flowed 85 bbl. of 24° to 26° gravity oil on a 12-hr. gauge, from perforations at 4070 to 4075 ft. in sand at 4070 to 4080 ft. Flow was through 3/16-in. choke with 375 lb. pressure on tubing and 550 lb. on casing. This well was plugged back to 4163 ft. from a total depth of 7511 ft. The test is important in that, besides being 2500 ft. east of the limits of the main Turkey Creek production, it was located on the downthrow side of the fault dividing Turkey Creek from the Saxet field, thus placing a considerable amount of condemned acreage back into the line of play.

North Agua Dulce Field.—Union Producing Company's A. B. Simmonds No. 1, 2½ miles northeast of the Agua Dulce field, was completed

on March 3 to discover the North Agua Dulce field from Frio sand at 4810 to 4834 ft. Flow of 60 bbl. of 48.2° to 52° gravity distillate, along with a high volume of gas, was through ¼-in. choke, under 1820 lb. tubing pressure and 1900 lb. casing pressure, from perforations at 4810 to 4834 ft. in casing set at 5478 ft. Total depth of the hole, before a plug-back operation, was at 8706 ft. This well topped First Oysters at 3660 ft., *Discorbis* at 3770 ft., *Heterostegina* at 3950 ft., Vicksburg at 6810 ft. and *Textularia Warreni* at 8521 ft. The producing sand showed saturation of 1 to 3 per cent, and a porosity of about 30 per cent. Geophysics show this area to be a rather large structure consisting of a domal anticline with faulting to the east.

Riverside Field.—The Riverside field, 8 miles northwest of Robstown, was brought in by Seaboard Oil Company's Ellen C. Wilson No. 1, which blew out on Nov. 26, at a depth of 6541 ft., ran wild, cratered and burned until Dec. 1, when it choked itself. It showed crude while burning. This well had encountered a gas sand at 4213 to 4224 ft., sandy shale and shaly sand carrying oil odor at 4935 to 4945 ft., a gas sand at 5242 to 5253 ft. and a gas sand at 6350 to 6378 ft., all in the Frio.

Three wells previously drilled in this area, together with other exploration work, had indicated this structural high, which probably is a domal anticline.

Stanolind Oil and Gas Company's Clark No. 1, 3000 ft. southeast of the crater, and drilled simultaneosly, was completed through perforations at 4888 to 4893 ft. in Frio sand for a flow of several million cubic feet of gas daily through 1⅜₄-in. choke, under pressures of 1450 lb. on tubing and 1550 lb. on casing. Total depth was 7015 feet.

New Sands in Existing Fields

Agua Dulce Field.—The 5300-ft. Frio sand in the Agua Dulce field was opened by Union Producing Company's Torbett No. 1, when it flowed 480 bbl. of 40° gravity crude through ¼-in. choke from perforations at 5295 to 5307 ft. This was important, not only because of the discovery of a new sand, but because heretofore wells in this field have produced only distillate and gas. In November, a new shallow Frio sand was opened in this field by G. P. Sheldon's E. H. Sands No. 1, which produced gas and distillate from sand at 4666 to 4675 feet.

Clara Driscoll Field.—H. M. Reed's A. D. Holloway No. 1 produced 103 bbl. of oil by artificial lift on a 6-hr. potential test to open a new Frio sand at 5333 to 5355 ft. This well had previously been abandoned at 4388 feet.

South Clara Driscoll Field.—In March, a new sand at 5340 to 5367 ft., in the Frio zone, was proved productive by Wellington and Seaboard Oil Company's L. M. Dugger No. 2, which flowed 8 bbl. of 36.2° gravity oil per hour through ⅜-in. choke from perforations at 5340 to 5367 ft.

This test missed the regular 3800 ft. zone but found other sands showing possibilities of production at 4648 to 4657 ft., at 4736 to 4748 ft., at 5076 to 5090 ft. and at 5289 to 5305 ft. During the last week in September, Heep Oil Corporation and Refugio Oil Co. completed their M. Fogers No. 3 for a flow of 500 bbl. of 42° gravity oil per day through $5/32$-in. choke from a new Frio sand at 5450 to 5460 feet.

Corpus Christi Field.—J. K. Culton's H. B. Baldwin No. 4, originally completed in the regular 4000-ft. sand, was deepened to 5761 ft., where it found a sand in the *Heterostegina* zone from 5157 to 5167 ft. Casing was perforated at 5159 to 5164 ft. and a flow of 131 bbl. of 36.5° gravity oil and 60 bbl. of salt water per day was obtained through $5/16$-in. choke under 825 lb. tubing pressure and 1400 lb. casing pressure. Later developments in this sand were disappointing.

Luby Field.—Seaboard Oil Company's No. 23 James Luby, in block 2, was completed during May in a new *Heterostegina* sand at 5171 to 5175 ft. for a flow of 144 bbl. of oil per day through $1/8$-in. choke.

Saxet Field.—In April, in the southwest part of the Saxet field, Sultex Oil Company's No. 1-B Taggart flowed 46 bbl. of 41.8° gravity oil on a 6-hr. test from a new deep sand level at 6835 to 6841 ft., to revive interest in that portion of the Saxet field. Flow was through $9/64$-in. choke and under 1200 lb. tubing pressure and 1330 lb. casing pressure.

On the west side of the Saxet field, Western Gulf Petroleum Company's Isensee No. 4 was completed in April for a flow of 145 bbl. of oil through $1/8$-in. choke, from perforations at 6464 to 6467 ft., to open a new sand level. Pressures were 1000 lb. on tubing and 1300 lb. on casing.

A new and deeper sand was found in May by Richardson Petroleum Company's M. Erigan No. 2, when it flowed 500 bbl. of white distillate and 3,000,000 cu. ft. of gas from perforations at 7315 to 7325 ft. through $1/8$-in. choke under pressures of 2300 lb. on tubing and 2500 lb. on casing. This test was first completed in the 5800-ft. level but was deepened to 7999 ft., where an electric test showed an almost solid sand body from 7250 to 7390 ft. in the Frio.

Deepest production in South Texas was found in October in this field by Richardson Petroleum Company's Cain and Sechrist No. 24, which had an initial production of 175 bbl. of distillate and 3,000,000 cu. ft. of gas per day from a depth of 9927 ft. This well attempted to blow out at 9927 ft.; although the blowout was averted, the drill stem stuck at 9895 ft., where it was cemented. Production was obtained through the drill pipe through $3/16$-in. choke, with a pressure of 3400 lb. on the drill stem. This well, on the southeastern side of the field, is across a downthrow fault separating it from the main field's deep production. This new level may be in the Vicksburg.

Stratton Field.—In March, a new Frio sand was found in the Stratton field by Camp Production Company's C. P. Wardner No. 4, sec. 16, in

the south portion of the field, which was completed flowing 163 bbl. of 54° gravity distillate per day from sand at 6273 to 6300 ft. Flow was through ¼-in. choke under 1900 lb. tubing pressure and 1975 casing pressure.

Extensions to Established Areas

Agua Dulce Field.—Union Producing Company's C. L. Galladay No. 1 provided a north extension to the Agua Dulce field when it flowed an estimated 10,000,000 cu. ft. of gas and 36 bbl. of gasoline per day through ¼-in. choke from perforations at 6730 to 6740 ft. Pressures were 2500 lb. on tubing and 2800 lb. on casing. Total depth was 8190 ft. The field was extended ¾ mile west by Union Producing Company's Perkins No. 1. This well produced 10,000,000 cu. ft. of gas and 50 bbl. of gasoline per day through perforations at 4830 to 4850 feet.

Flour Bluff Field.—The first submerged completion on the South Texas Coast was provided in the Flour Bluff field by Sinclair-Prairie Oil Company's State No. 1, which flowed 500 bbl. of oil daily through ⅛-in. choke from perforations at 6653 to 6660 ft. in *Marginulina* sand. Total depth was 6666 feet.

San Patricio County

East White Point Field.—The East White Point field was brought in on Feb. 24 by Plymouth Oil Company's No. 1 Mrs. F. Brigham, 8 miles southwest of Taft and 2 miles east of the White Point field, San Patricio County. Sandy shale and sand carrying oil and gas show were found at 5627 to 5657 ft., and well-saturated sand was cored at 5657 to 5665 ft. in the Frio zone. On completion, this well flowed 216.6 bbl. of 38.3° gravity oil, through 9/16-in. choke, under 950 lb. tubing pressure and 1100 lb. casing pressure, through perforations at 5661 to 5664½ ft. Casing was set at total depth of 5665 ft. This well found Base of Oakville at 3636 ft., top of Catahoula at 4085 ft., base of Catahoula at 4565 ft., top of *Discorbis* at 4636 ft. and top of *Heterostegina* at 4934 ft. This structure, a faulted and cross-faulted, domal anticline, is expected to cover a rather large area. The discovery well also had shows in sands at 4976 to 4983 ft. in the *Heterostegina*, and in the Frio at 5029 to 5065 ft.; these sands may prove productive elsewhere on this structure. The producing sand showed saturation of 2.6 to 4.8 per cent, and porosity of 24 to 33 per cent.

East Plymouth Field.—On May 8, Humble Oil and Refining Company's Smith and Talbert No. 1 was completed for a flow of an estimated 10,000,000 cu. ft. of gas from *Heterostegina* sands at 4808 to 4836 ft. through perforations at 4808 to 4810 ft. Flow was through 5/32-in. choke and under pressures of 1950 lb. on tubing and 2100 lb. on casing. Drill-stem tests of this sand recovered several hundred feet of oil with

some salt water. However, because of mechanical difficulties, oil was not obtained on completion.

Porosity of this sand ranged between 28 and 34 per cent, and cores at 4819 to 4820 ft. showed 5 per cent saturation. This well, which is probably on a faulted anticline, found the *Heterostegina* (Greta) sand about 100 ft. higher than the level at which the latter is found in the Plymouth field; since the Humble well is 1¾ miles east and downdip, faulting between these two areas is indicated.

New Sands in Existing Fields

Plymouth Field.—A new Frio sand in the Plymouth field was uncovered by Plymouth Oil Company's E. H. Welder No. 95-C when it flowed 180 bbl. of 40° gravity oil through ⅛-in. choke from perforations at 6156 to 6159 ft. Pressures were 650 lb. on tubing and 1000 lb. on casing. A sand carrying distillate showings was also found at 5855 to 5895 ft. by this well.

Extensions to Established Areas

Aransas Field.—Frank Grote's Carlock No. 1, situated ¼ mile from the city limits of Aransas Pass, was completed in October for a flow of 110 bbl. of 41° gravity oil on a 12-hr. gauge through 3/16-in. choke, from perforations at 7127 to 7133 ft. in Frio sand logged at 7111 to 7143 ft. This was a one-mile southwest extension to the Aransas (McCampbell) field.

White Point.—The White Point gas field was given its first oil producer in the completion of J. K. Culton's No. 1 White Point Development Co., from *Heterostegina* sand at 4910 to 4961 ft. The well flowed 50 bbl. of oil daily through 5/32-in. choke.

Acknowledgment

The author wishes to extend his appreciation and thanks to James J. Halbouty, student geologist, for his patient and valuable assistance in assembling and compiling data from many sources and in the final preparation of this report; also to V. E. Cottingham, Director of Production for the Texas Railroad Commission, for his courtesies in permitting valuable production data on the district to be obtained from the Commission.

West Texas Oil Developments in 1938

By Peter P. Gregory,* Member A.I.M.E., E. W. Owen† and John G. H. Crump,‡ Member A.I.M.E.

(New York Meeting, February, 1939)

A noticeable decrease in activity characterized the year 1938 in the West Texas area. The total number of wells completed dropped to 2045 for 1938[1] as compared with 2806 completions in 1937,[1] a decline of 27.12 per cent. This trend contrasts the sharp increase of 76.29 per cent in completions in 1937 over the 1936 total. Of 2045 well completions during 1938,[1] 1788 were oil wells,[1] 16 were gas producers[1] and 241 were listed as failures.[1] During 1938 the ratio of dry holes drilled to oil-producing or gas-producing wells completed was one dry hole to each 7.48 oil wells, which compares with one dry hole drilled to each 7.477 oil wells in 1937. Nearly 200 wells drilled during 1938 in West Texas were either wildcat or partly wildcat wells, an increase of about 25 over the year 1937, when approximately 175 wells drilled were so classified. The 200 exploratory wells drilled represent about 10 per cent of the total number of wells completed.

West Texas produced 71,257,541 bbl.[1] of oil in 1938 as compared with 75,743,000 bbl.[2] of oil in 1937, a decrease of 4,485,459 bbl., or a 5.92 per cent decline. By comparison, West Texas produced 22.36 per cent more oil in 1937 than during 1936. In December 1938, the 9247 producing oil wells in West Texas[1] averaged 22.08 bbl. per day per well as compared with December 1937, when 7571 wells[1] produced an average of 25.18 bbl. per day per well, or a decline in daily well average of 12.32 per cent.

Discoveries

No outstanding new fields were discovered in West Texas during 1938, in spite of continued, active wildcatting operations. Several new oil-producing areas were found, however, the value of which is still unknown.

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[1] *Oil and Gas Journal.*

[2] U. S. Bureau of Mines.

Crockett Field.—Crockett field was discovered on April 14, 1938, when Choate and Hogan's No. 1 State University K lease, in sec. 17, University block 14, Crockett County, was completed in Permian lime at a depth of 1627 ft. The well was plugged back to 1575 ft. and produced 104 bbl. of 30.7° gravity oil on a 24-hr. pumping test. There were seven producing wells in the field at the end of the year but no pipe-line outlet was yet available.

Dean Field.—A small field was indicated in Cochran County with the completion of Wiggins and Lawson No. 1 Dean of Labour 26, League 92, Lipscomb County school lands. The completion was made in Permian limestone at a depth of 5077 ft. on March 16, 1938. Initial production was 332 bbl. per day through tubing on air lift. This discovery may possibly be an extension of the Duggan field.

Dune Field.—Dune field, about 2 miles north and west of the Church-Fields pool in Crane County, was discovered by Magnolia Petroleum Co. The discovery well, University No. 1, in sec. 16, University block 30, was completed for an initial production of 52 bbl. per day through tubing, from a depth of 3335 ft. in Permian limestone. The well was plugged back from 3672 ft. to shut off water. Five producing wells had been completed by the end of the year, with four wells drilling at that time.

Emma Field.—Emma field, in south Andrews County, was discovered in December 1937. Rhodes and Thompson's No. 1 Emma Cowden, the discovery well, was completed on Aug. 3, 1938, in Permian limestone at a depth of 4200 ft. The well flowed 635 bbl. of oil through a 34-in. choke after being treated with 6500 gal. of acid. Six producing wells were listed in this field at the end of 1938.

Payton Field.—Payton field, in Pecos and Ward Counties, was discovered late in 1937. J. J. Dorr No. 1 Payton, the discovery well, was completed in Yates sand at a depth of 2037 ft., flowing 39 bbl. of oil in the first 24 hr. through 2-in. tubing. Fifty-eight wells were completed during 1938 in this new field.

Shearer Field.—W. H. Street No. 1 Texas Shearer was completed at 1432 ft. for 100 bbl. of 32.9° gravity oil per day to open the Shearer field, in Pecos County, from the Pecos Valley sand, on July 20, 1938. The well was deepened in November 1938 to 1445 ft. and was shot from 1400 to 1445 ft. with 50 quarts of nitroglycerin, which resulted in a flow of 240 bbl. of oil during the first 12 hr. There were nine producing wells in the field at the end of 1938.

Garza County.—A new oil-producing area was discovered late in December 1938 in Garza County, where Gulf Oil Company's No. 1 Swenson was reported to have found four pay zones and was tested in the fourth zone at 7327 to 7334 ft. and flowed 150 bbl. of 36.7° gravity oil in 9 hr. The well was still testing at the end of the year.

TABLE 1.—*Oil and Gas Production in West Texas in* 1938

Line Number	*County*, Field	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[a]	To End of 1938	During 1938
1	*Andrews:* Deep Rock (Walker-Fuhrman)	8	4,370	0	2,024,403	527,025
2	Emma	2	640	0	45,950	43,679
3	Means	4	10,240	0	2,259,070	774,965
4	Parker	4	160	0	48,667	11,243
5	Nix	0	40	0	*y*	*y*
6	Shafter Lake	0	0	40	0	0
7	*Cochran:* Dean	0	40	0	*y*	*y*
8	Duggan	2	4,000	0	0	0
9	*Crane-Upton:* Church-Fields-McElroy-McClintic	13	13,500	0	108,572,882	3,667,195
10	*Crane:* Dune	0	800	0	2,388	2,388
11	Sand Hills (Permian)	8	3,380	0	923,606	378,552
12	Sand Hills (Ordovician)	3	500	0	184,844	73,466
13	*Crockett:* Crockett	1	*y*	0	8,631	8,631
14	World-Powell	13	2,000	0	6,268,485	302,979
15	*Dawson:* Albaugh	2	160	0	753	0
16	Wilson	1	40	0	2,039	0
17	*Ector:* Addis (S. Cowden)	6	1,500	40	875,480	97,413
18	Cowden (N. Cowden)	8	9,500	0	9,290,320	2,409,890
19	Foster	3	7,000	0	2,764,842	1,825,048
20	Goldsmith	4	40,000	*x*	9,195,168	5,394,979
21	Harper	5	4,500	0	3,115,094	2,758,382
22	Landreth-Johnson	4	40	0	51,811	13,436
23	*Ector-Crane:* Penn-Jordan-Waddell	11	16,500	0	21,271,540	2,389,848
24	*Gaines:* Landreth-Kirk	2	40	0	1,500	0
25	Seminole	2	5,000	0	153,497	125,442
26	*Gaines-Yoakum:* Wasson-Denver	2	40,330	0	2,170,151	1,980,178
27	*Garza:* Emerald (Garza)	14	320	0	89,618	13,308
28	*Glasscock:* Dodson-Duffy	2	160	0	9,361	6,337
29	*Glasscock-Howard:* Chalk-Roberts[1]	13	21,700	0	82,620,287	5,132,948
30	1400-foot pay	12	1,700	0	[1]	[1]
31	1700-foot pay	13	4,000	0	[1]	[1]
32	2200-foot pay	10	8,000	0	[1]	[1]
33	2500-foot pay	11	2,000	0	[1]	[1]
34	3000-foot pay	11	6,000	0	[1]	[1]
35	*Hockley:* Slaughter	1	13,000	0	155,792	145,517
36	*Howard:* Iatan-Denman	13	6,500	0	9,981,331	2,207,761
37	Moore	0	640	0	*y*	21,254
38	*Irion:* Irion Co.	9	340	0	126,059	6,276
39	*Loving:* Mason (Kyle)	2	260	0	209,889	121,329
40	Wheat	13	4,500	0	7,379,301	457,636
41	*Mitchell:* Westbrook	18	4,000	0	8,673,579	267,008
42	*Pecos:* Masterson	9	640	0	704,982	192,170
43	McKenzie	3	160	0	2,447	0
44	Netterville	4	1,600	0	244,511	82,971
45	Pecos Valley	10	3,200	80	1,063,456	254,376
46	Pryor Richards	10	160	0	27,529	300
47	Shearer	0	*y*	*y*	72,163	72,163
48	Tobarg	9	1,200	0	5,238,561	615,840
49	Taylor-Link (Sand)	10	450	0	514,291*e*	21,000
50	Taylor-Link (Lime)	10	1,620	0	4,679,547*e*	444,338*e*
51	White & Baker	4	320	640	7,563	4,467
52	Yates (Sand)	5	700	0	347,094	43,981
53	Yates (Lime)	12	20,000	0	239,664,668	6,728,426
54	*Pecos-Ward:* Payton	1	2,200	0	291,292	291,292
55	*Regan:* Big Lake (2400-ft. pay)	15	275	0	[2]	[2]
56	Big Lake (3000-ft. pay)	15	3,000	0	[2]	[2]

[a] Footnotes to column heads and explanation of symbols are given on page 240.
[1] Production totals for all pay zones included under field totals.
[2] Included under Big Lake Ordovician because no separate records are available. At end of 1937 the 2400-ft. and 3000 ft. pays had produced 62,161,859 bbl. combined. The Ordovician had produced 25,698,390 bbl. at end of 1937.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.: To End of 1938	Total Gas Production, Millions Cu. Ft.: During 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	Number of Oil and/or Gas Wells: During 1938: Completed	Number of Oil and/or Gas Wells: During 1938: Abandoned	Number of Oil and/or Gas Wells: At End of 1938: Producing Oil[b]	Number of Oil and/or Gas Wells: At End of 1938: Producing Gas[c]	Oil-production Methods at End of 1938: Number of Wells: Flowing	Oil-production Methods at End of 1938: Number of Wells: Pumping	Oil-production Methods at End of 1938: Number of Wells: Miscellaneous	Pressure, Lb. per Sq. In.[d]: Initial	Pressure, Lb. per Sq. In.[d]: Average at End of 1937	Pressure, Lb. per Sq. In.[d]: Average at End of 1938
1	*x*	*x*	52	21	0	51	0	41	10	0	*e*1,800	*x*	*y*
2	*x*	*x*	9	8	0	9	0	9	0	0	*e*1,555	*x*	*x*
3	2,500	1,025	76	22	0	73	3	47	2	G24	*e*1,900	*e*1,611	*e*1,607
4	0	0	2	0	0	2	0	0	2	0	*y*	*y*	*y*
5	0	0	1	1	0	1	0	1	0	1	*y*	*y*	*y*
6	*y*	*y*	1	1	0	0	1				*y*	0	*y*
7	*y*	*y*	1	1	0	0	0	1	0	0	*x*	*x*	*x*
8	0	0	8	5	0	8	0	5	3	0	1,100	1,100	700
9	*y*	*y*	474	34	1	473	0	129	334	10 ±	725	*y*	*y*
10	*x*	*x*	3	3	0	3	0	1	2	0	740		740
11	900	*y*	49	13	0	49	0	44	5	0	2,100	*y*	1,822
12	*x*	*y*	6	2	0	6	0	4	2	0	*y*	*y*	*y*
13	*x*	*x*	*y*	8	0	8	0	0	8	0	*y*	*y*	*y*
14	*x*	*x*	64	2	0	42	0	0	42	0	*x*	*x*	*y*
15	*x*	0	2	0	*y*	0	0	0	0	0	*x*	*x*	*y*
16	*x*	0	1	0	1	0	0	0	0	0	*y*	*y*	*y*
17	*x*	*x*	17	2	2	12	0	7	6	0	*x*	*x*	*x*
18	34,212*e*	7,712	226	45	0	226	0	205	19	*y*	1,740	1,340	1,330
19	1,710*e*	1,110*e*	205	120	0	205	0	99	106	*y*	1,521	*x*	*x*
20	*y*	10,057	606	244	0	602	4	576	10	{14, G16}	1,675	1,470	1,431
21	*x*	*x*	183	161	0	183	0	141	37	5	900	*y*	*y*
22	*x*	*x*	2	0	0	2	0	0	2	0	*x*	*x*	*x*
23	*y*	*y*	309	83	0	307	2	*y*	*y*	*xy*	*y*	*y*	*y*
24	0	0	1	0	0	0	0	0	0	0	*y*	*y*	*y*
25	3,253	1,753	9	6	0	9	0	10	0	0	2,000	1,936	1,908
26	*x*	*y*	152	131	0	152	0	146	5	1	2,050	*x*	*y*
27	*x*	*x*	8	0	0	8	0	0	8	0	*x*	*x*	*x*
28	*x*	*x*	2	0	0	2	0	0	2	0	*x*	*x*	*x*
29	*x*	*x*	828	45	0	828	0	0	828	0	See data for separate pay depths below		
30	*x*	*x*	272	2	0	272*x*	0	0	272	0	*x*	*x*	*x*
31	*x*	*x*	59	0	0	59	0	0	59	0	*x*	*x*	*x*
32	*x*	*x*	49	0	0	49	0	0	49	0	*x*	*x*	*x*
33	*x*	*x*	283	18	0	283	0	0	283	0	*x*	*x*	*x*
34	*x*	*x*	165	25	0	165	0	0	165	0	*x*	*x*	*x*
35	*y*	*y*	15	12	1	14	0	14	0	0	*y*	*y*	*y*
36	*x*	*x*	250	18	0	250	0	8	242	0	*x*	*x*	*x*
37	*x*	*x*	6	*y*	*y*	6	0	*y*	*y*	*y*	*y*	*y*	*y*
38	*x*	*y*	17	0	0	9	0	0	9	0	*x*	*x*	*y*
39	Fuel for drilling only		8	3	0	8	0	7	1	0	*x*	*x*	*x*
40	*x*	*x*	79	2	*y*	75	0	53	14	{6, G 3}	1,650	750	673
41	*x*	*x*	136	0	29	95	0	0	96	0	1,000*e*	*y*	*y*
42	*x*	*x*	27	5	0	23	0	*y*	*y*	*y*	*x*	*x*	*y*
43	*x*	0	1	0	0	0	0	0	0	0	*x*	*x*	*x*
44	*x*	*y*	20	5	0	20	0	*y*	*y*	*y*	*x*	*x*	*y*
45	*x*	*y*	125	56	0	110	0	*y*	*y*	*y*	*x*	*x*	*y*
46	*x*	*x*	3	0	0	0	0	0	2	0	*x*	*x*	*x*
47	*y*	*y*	13	13	0	13	0	13	0	0	*y*	*y*	*y*
48	*x*	*x*	203	6	0	203	0	0	203	0	*x*	*x*	*y*
49	*x*	*x*	10	0	1	9	0	0	9	0	*x*	*x*	*x*
50	*x*	*x*	64	6	3	60	1	1	59	0	*x*	*x*	*x*
51	*x*	*y*	7	3	1	3	1	3	0	0	900*e*	*x*	*y*
52	*x*	*x*	10	0	0	10	0	0	10	0	100	*x*	*y*
53	115,063	1,458	552	10	1	549	0	518	29	5	700	535	533
54	363*e*	363*e*	57	57	0	57	0	57	0	0	750*e*	*y*	*y*
55	*x*	*x*	21	0	0	0	0	0	*y*	0	*x*	*x*	*x*
56	*x*	*x*	261	0	0	198	0	0	198	0	*y*	*y*	*y*

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1938: Gravity A.P.I. at 60° F.: Weighted Average	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
1	*x*	Big Lime	Per	4,625	4,350	D	Por	25	A	Permian lime	5,088
2	34.6	Big Lime	Per	4,225	4,190	D	Por	25	A	Permian lime	4,342
3	29	Big Lime	Per	4,535	4,475	D	Cav	20	A	Permian	5,227
4	29.5	Big Lime San Andres	Per	4,790	4,627	D	Por	5	MC	Permian (San A)	4,814
5	27	Big Lime	Per	4,526	*y*	D	Por	*y*	A	Permian	4,526
6		Yates	Per	2,952	*y*	*y*	*y*	*y*	*y*	Permian	2,952
7	30	Yates	Per	5,077	*y*	*y*	*y*	*y*	*y*	Permian	5,077
8	30.6	Big Lime San Andres	Per	5,060	5,000	D	Por	65	MC	Permian	5,098
9	32	Big Lake Lime	Per	3,000	2,800	D	15±	75	A	Ordovician	12,786
10	36	Big Lime	Per	3,270	3,155	L	Por	36*y*	*x*	Permian	3,503
11	35	Big Lime	Per	4,421	4,299	D	Por	50	AD	Ordovician	6,450
12	46	"Simpson" Ellenberger	Ord	6,100	5,950	DS	Cav	18	AF	Pre-Cambrian	7,158
13	30	Big Lime	Per	1,538	*y*	DL	Por	*y*	*y*	Permian	*y*
14	29	Big Lime	Per	2,550	2,450	DL	Por	13	A	Ordovician	8,830
15	31	Big Lime	Per	5,038	4,970	DL	Por	*y*	A	Permian	5,055
16	37	Delaware	Per	5,100	*y*	S	Por	*y*	A	Permian	5,100
17	32	Big Lime	Per	4,350	4,000	DS	Por	*x*	A	Permian	4,627
18	34	Big Lime	Per	4,350	4,000	DS	Por	40±	A	Permian	4,971
19	36	Big Lime	Per	4,310	4,100	DL	Por	35±	A	Permian	4,517
20	36	Big Lime	Per	4,225	4,150	D	Por	70	A	Permian	4,509
21	37	Big Lime San Andres	Per	4,200	4,000	D	Por	120	MC	Permian	4,518
22	36	Big Lime	Per	4,166	4,100	DS	Por	30	A	Permian	4,166
23	36	Judkins pay	Per	3,600	3,450	D	Cav	40	A	Permian	4,002
24	27	Big Lime	Per	4,850	4,796	DS	Por	50	A	Permian	4,870
25	37.5	Big Lime	Per	5,050	5,005	L	Por	50	A	Permian	5,116
26	34	Big Lime	Per	5,054	4,880	L	Por	*y*	A	Permian	5,346
27	39	Big Lime	Per	2,510	2,000	SL	Por	10	A	Permian	4,801
28	*y*	Big Lime	Per	2,664	2,632	DL	Por	4	D	Permian	3,247
29		See data for separate pay depths below								Ordovician	10,960
30	33	Yates sand	Per	1,400	1,280	Sd	Por	20	A	Ordovician	10,960
31	32	"1700-ft. pay"	Per	1,750	1,650	SS	22	20	A	Ordovician	10,960
32	27	"2200-ft. pay"	Per	2,300	2,150	L	Por	30	A	Ordovician	10,960
33	28	"2500-ft. pay"	Per	2,600	2,500	L	Por	30	A	Ordovician	10,960
34	30	"3000-ft. pay"	Per	3,000	2,800	L	Por	*x*	A	Ordovician	10,960
35	32	"Duggan Pay"	Per	5,000	4,900	D	*y*	50	MC	Permian	5,521
36	27	Big Lime	Per	2,800	2,450	DL	Por	50	A	Permian	4,220
37	*y*	*y*	*y*	3,400	3,200	*y*	*y*	*y*	*y*	*y*	*y*
38	39	Yates sand	Per	1,410	1,400	Ss	Por	10	M	Permian	3,972
39	39	Delaware S.S.	Per	3,953	3,931	Ss	Por	5	T	Permian	4,165
40	38	Delaware sand	Per	4,304	4,297	Ss	Por	7	MC	Delaware	5,083
41	24	Big Lime	Per	3,000	2,800	DL	Por	50	MC	Pennsylvanian	5,250
42	28	Pecos Valley sand	Per	1,400	1,200	Ss	Por	5	M	Permian	1,675
43	*y*	Yates sand	Per	1,378	1,338	Ss	Por	10	T	Permian	2,800
44	34	Yates sand	Per	2,300	2,225	Ss	Por	15	A	Permian	2,459
45	31	Yates sand	Per	1,600	1,300	Ss	Por	15	A	Permian	2,550
46	24	Yates sand	Per	1,400	1,385	SH	Por	25	A	Permian	4,375
47	35	Pecos Valley sand	Per	1,465	1,415	Ss	Por	*y*	*y*	*y*	*y*
48	19	Tobarg sand	Cre	445	400	Ss	Por	20	AL	Permian	1,400
49	28	Yates sand	Per	1,016	970	S	Por	30	A	*y*	*y*
50	30	Big Lime	Per	1,675	1,630	DL	Por	15	A	Permian	2,185
51	31	Big Lime	Per	1,700	1,650	Ds	Por	10	A	Ordovician	9,811
52	32	Yates sand	Per	1,100	900	Ss	Por	15	AL	Permian	1,852
53	30	Yates Lime	Per	1,450	1,310	DL	Cav	100	A	Permian	1,938
54	37.5	Yates sand	Per	2,050	1,950	Ss	Por	100	A	Permian	2,102
55	35	Big Lime	Per	2,500	2,375	Ss	Por	40	A	Lower Ordovician	9,562
56	36	Big Lake Lime	Per	3,000	2,960	D	Por	60	AD	Lower Ordovician	9,562

Extensions

The greater number of wells completed in 1938 in West Texas were in field extensions and their development.

Slaughter field, Hockley County, was extended to the east by the drilling of Gulf Oil Company's well No. 2 Mallet Land & Cattle Co. in Labour 25, League 34, Concho County school land. The well was drilled to a depth of 5090 ft. and plugged back to 5070 ft. where it tested 200 bbl. of oil per day after shot and acidization. The Texas Company well No. 1B Mallet, in Labour 1, League 52, Scurry County school land, extended the field to the west when it made 179 bbl. of oil in 24 hr. on a production test through 2½-in. tubing on ⅝-in. choke after shot and acidization from total depth of 5035 ft. Sid Richardson No. 1 Bob Slaughter in Labour 59, League 39, Maverick County school land, extended the field to the north, when it established a potential production of 486 bbl. per day. Total proven acreage in the field appears to be

Table 1.—(*Continued*)

Line Number	*County*, Field	Age. Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.	
			Oil	Gas[a]	To End of 1938	During 1938
57	Big Lake (Ordovician)	10	1,300	0	90,296,628	2,437,649
58	Grayson	10	640	0	563,317	44,546
59	*Reeves:* Toyah	19	640	0	6,500	0
60	*Scurry:* Ira-Northwest	14	640	0	126,550	13,436
	Upton-Crane: McCamey-Hurdle					
61	Herrington, Crane, Cowden	13	20,000	0	44,554,205	5,813,496
62	Cordova-Union (Webb-Ray)	3	160	0	31,441	8,278
63	*Ward:* Dobbs	2	40	0	13,113	2,510
64	Estes	3	5,000	0	5,812,349	2,449,431
65	Monroe	8	40	0	34,546	8,266
66	Ward County[3]	10	36,000	1,000	47,842,359	9,032,000
67	Shipley	9	2,500	0	*y*	476,750
68	*Winkler* Bashara[4]					
69	*Winkler:* Emperor	3	1,560	170	1,282,882	461,293
70	Halley	4	820	0	*y*	165,801
71	Hendrick	12	11,040	160	192,546,384	4,046,916
72	Henderson	3	2,600	0	2,571,134	1,022,825
73	Kermit	10	18,260*x*	*x*	17,689,706	5,683,705
74	Keystone	3	6,000	0	2,684,477*e*[5]	1,009,317*e*
75	Leck	11	960	0	3,449,642	127,924
76	Scarbrough	12	1,920	0	3,819,821	580,857
77	Sealey	6	400	0	*y*	134,063
78	*Yoakum:* Bennett	2	2,240	0	947,194	823,732
79	Bohago-Bond (West Pool)	1	40	0	6,639	6,139

[3] Includes both North Ward and South Ward fields.
[4] Became part of Keystone-Colby sand field on Nov. 1, 1938.
[5] Includes Bashara cumulative production.
[6] Includes Keystone "Colby sand" production.

about 11,000 acres with 12 producing wells in the field at the end of the year.

Seminole field, Gaines County, was extended approximately 3½ miles north and northwest by the completion of the Osage Drilling Co. well No. 1 Riley in sec. 249, and definite assurance of oil production in Adams-Bradley well Crain No. 1 in sec. 216, block G, W.T.R.R. Survey. One mile extension to the east was provided by Amerada Robertson No. 1 in sec. 196. These extensions indicated total productive area of the field to be more than 5000 acres. There was no pipe-line outlet in the field for the nine producing wells at the end of the year.

Ector County led West Texas in completions and locations, greatest development being in the Goldsmith, Harper and Foster pools, which accounted for a combined total of 520 new producing wells during 1938.

Ordovician Exploration

A decline was noted in the number of wildcat tests drilled in West Texas in search of Ordovician production in 1938. During the preceding year 12 such tests were made as against 7 in 1938. Outstanding

Table 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					Oil-production Methods at End of 1938			Pressure, Lb. per Sq. In.[d]		
				During 1938		At End of 1938		Number of Wells				Average at End of	
	To End of 1938	During 1938	Completed to End of 1938	Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Flowing	Pumping	Miscellaneous	Initial	1937	1938
57	*y*	*y*	24	0	0	13	0	10	1	2	3,600	*y*	*y*
58	*x*	*y*	5	0	0	5	0	0	5	0	*x*	*x*	*y*
59	*x*	0	35	0	*y*	0	0	0	0	0	*x*	0	0
60	*x*	*y*	10	0	0	9	0	0	10	0	*x*	*x*	*y*
61	*x*	*x*	985	154	7	968	0	3	965	0	*x*	*x*	*x*
62	*x*	*y*	5	2	0	4	0	0	4	0	*x*	*x*	*x*
63	*x*	*x*	2	0	1	1	0	0	1	0	*x*	*x*	*x*
64	*x*	*y*	300	68	0	298	0	284	10	2	*x*	*e*1,100	*e*1,000
65	*x*	*x*	1	0	0	1	0	1	0	0	*x*	*x*	*y*
66	*x*	*x*	1,460	190	*y*	1,446*x*	14	*y*	*y*	*y*	*x*	*x*	*x*
67	*x*	*x*	97	5	*x*	96	1	11	85	2	*x*	*y*	*y*
68													
69	*x*	*x*	73	17	*y*	70	3	66	4	0	*e*1,300	*y*	*y*
70	*x*	*x*	26	0	*y*	25	1	18	7	0	*e*1,235	*e*1,050	*e* 900
71	*y*	*y*	631	2	14	36.7	3	15	270	{74; G 8}	*e*1,600	*x*	*x*
72	2,100	*y*	126	13	0	126	0	123	3	0	1,450	1,308	*y*
73	31,600*e*	*y*	904	117	0	889	14	798	88	3	1,450	931	806
74	*x*	*x*	100	27	0	100*y*	0	90	10	0	2,000	*y*	*y*
75	*x*	*y*	16	0	1	8*x*	0	0	8	0	*y*	100	100
76	*x*	*y*	124	27	0	124	0	85	39	0	1,200	*y*	*y*
77	*x*	*x*	23	3	0	23	0	18	5	*y*	*y*	*y*	*y*
78	0	0	55	50	0	55	0	1	0	0	*y*	*y*	*y*
79	0	0	1	0	0	1	0						

among the Ordovician tests to be abandoned was Magnolia Petroleum Company's No. 1 McKee, in the Imperial area in northern Pecos County. This well was carried to a total depth of 6267 ft. in the Ellenberger limestone, where sulphur water was encountered. The well was considered promising for production, inasmuch as some crude oil was actually recovered on formation tests higher in the Ordovician section.

It appears that oil operators consider northern Pecos County as most promising for Ordovician discoveries and several new Ordovician tests are under way at the present time in that area.

Prices for Crude Oil

Crude price changes in West Texas were made effective on Oct. 11, 1938. Humble Oil and Refining Co. announced a change from its previous schedule of \$0.78 per bbl. for all crude below 26° gravity, with a \$0.02 differential per degree, with top price of \$1.08 for oil of 40° gravity and above, to a price of \$0.53 per bbl. for crude of 20° gravity, with a \$0.02 differential per degree upward with top price of \$0.95 for 40° gravity and above, an average decline of 13¢ per bbl., or 12.037 per cent. Mag-

Table 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1938	Producing Formation								Deepest Zone Tested to End of 1938	
	Gravity A.P.I. at 60° F.	Name	Age[e]	Depth, Average in Feet		Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
	Weighted Average			Bottoms of Productive Wells	To Top of Productive Zone						
57	44	Ellenberger	Pen	8,900	8,200	L	Por	*x*	D	Lower Ordovician	9,562
58	32	Big Lime	Per	3,100	3,050	DL	Por	*y*	D	Mississippian	9,967
59	27	Big Lime	*y*	100	100	*y*	*y*	*y*	MC	Pennsylvanian	5,250
60	25	Big Lime	Per	2,395	2,320	DC	Por	25	A	Permian	4,528
61	28	Big Lime	Per	2,300	2,250	DL	Por	30	A	Permian	4,610
62	25	Big Lime	Per	2,150	2,060	DL	Por	*y*	A	Permian	2,176
63	*y*	Shipley-Hazlett	Per	2,570	2,555	Ss	Por	6	*y*	Permian	2,600
64	35	Estes sand	Per	2,950	2,450	Ss	Por	15	A	Permian	3,000
65	29	Delaware sand	Per	4,675	4,665	S	Por	4	T	Permian	4,692
66	36	O'Brien sand	Per	2,700	2,500	SD	*y*	50	ML	Permian	4,825
67	32.0	Shipley Lime	Per	3,100	3,075	D	Por	10	A	Permian	4,400
68											
69	33	O'Brien sand	Per	3,100	2,833	Ss	Por	40	Ac	White Horse	3,145
70	30.5	O'Brien and White Horse	Per	3,200	3,100	Ss	Por	22	Ac	San Andres ?	3,855
71	28	Big Lime	Per	2,900	2,600	D	Por	*y*	A	Permian	*y*
72	30	Big Lime	Per	3,075	3,025	DL	Cav	30	A	Permian	3,450
73	34	Permian sand and sandy lime	Per	3,050	2,825	DL	Por	10	A	Permian	3,414
74	37	Big Lime, Yates sand	Per	3,500	3,200	L-S	*y*	30	A-D	Permian	4,463
75	28.1	Big Lime	Per	3,100	3,000	DL	Cav	*y*	A	Permian	3,780
76	35.0	O'Brien sand	Per	3,400	2,860	Ss	Por	35	MC	Permian	3,565
77	35	O'Brien sand	Per	3,200	3,100	D, S	*y*	20	A	Permian	3,500
78	31	Big Lime	Per	5,260	5,050	DL	Por	45	MC	Permian	5,255
79				5,225	5,168						

nolia Petroleum Co. posted a crude-oil price schedule almost identical with that of the Humble Oil and Refining Co., the exception being that a price of \$0.63 per bbl. was quoted on gravities below 25. The Texas and Shell companies followed Magnolia Petroleum Company's postings, except that the top price was \$0.87 per bbl. for all crude oil of 36° gravity and above.

Conclusions

The allowable set for West Texas for December 1937 was 6,071,184 bbl. for 7571 wells,[3] or an average daily allowable per producing well of 25.87 bbl. per day. In contrast, for December 1938 an allowable of 6,538,367 bbl. was set for the 9247 producing wells,[3] or an average daily allowable of 22.80 bbl., a decline of 11.47 per cent. If West Texas is allowed to produce 70,000,000 bbl. of oil during 1939 and as many as 1200 new wells will be completed during the year, the per-well per-day allowable should drop to approximately 18 bbl. by December 1939. It is apparent that some form of curtailment of drilling operations must be made in West Texas to prevent the per-well per-day allowable production dropping below the economic limit. Wider spacing in proven fields with a consequent reduction in the number of wells drilled is the most logical step to be taken.

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[3] R. W. Byram; Texas Railroad Commission Schedule.

Oil and Gas Development in Utah in 1938

By C. E. Shoenfelt,* Member A.I.M.E.

There was very little oil activity in Utah in 1938. A few wildcat tests were drilled and the well at Cane Creek, started in 1937, was in active operation, but failed to reach its objective by the close of the year.

The Clay Basin field in Daggett County, northeastern Utah, was extended about a mile east by the Mountain Fuel Supply Co. with the completion early in June of No. 3-D Murphy, NW. NW. SW. of sec. 23-3N-24 E. This well had an initial production of 16,000,000 cu. ft. of gas a day under 2160 lb. pressure, from Dakota sand at 5918 to 5925 ft. after plugging back from a total depth of 6035 feet.

The Clay Basin field, in the few years it has been in operation, has developed into a gas field of major importance. Approximately 1300 acres has now been proved by development. Six wells are on production, five of which were completed in Dakota sand and the sixth in a sand in the Frontier formation. The field was connected to the Salt Lake line

Table 1.—*Oil and Gas Production in Utah in* 1938

Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					Oil Production Methods at End of 1938
										During 1938		At End of 1938		Number of Wells
			Oil	Gas[a]	To End of 1938	During 1938	To End of 1938	During 1938	Completed to End of 1938	Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Pumping
1	Ashley Valley, *Uinta*..........	13		240			21,597	5,897	5	0	0		2	
2	Cisco, *Grand*..............	14		2,000			31,280	0	13[1]	0	0			
3	Clay Basin, *Daggett*...........	11		2,800			58,301	37,086	7	1	0		6	
4	Farnham, *Carbon*.............	15		600			15,258	438	2	0	0		1	
5	San Juan, *San Juan*..........	29	160						129	0	0			
6	Virgin, *Washington*...........	31	450		172,250	2,000			75	1	2	15		15
7	Total..................		610	5,640			126,436	43,421	231	2	2	15		

[a] Footnotes to column heads and explanation of symbols are given on page 204.
[1] Field abandoned and all wells plugged.

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of the Mountain Fuel Supply Co. in 1937 by 21 miles of 10-in. pipe, which joins the main trunk line 25 miles northwest of Hiawatha.

Acknowledgment

The author is indebted to Mr. W. T. Nightingale, of The Mountain Fuel Supply Co., and Mr. A. E. Brainerd, of Continental Oil Co., for valuable assistance in the preparation of this report.

Table 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1938	Producing Rock								Deepest Zone Tested to End of 1938	
	Initial	Average at End of		Gravity A.P.I. at 60° F.	Name	Age[a]	Depth, Average in Feet		Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Name	Depth of Hole, Ft.
		1937	1938	Weighted Average			Bottoms of Productive Wells	To Top of Productive Zone						
1	580	200	180		Morrison	Jur	1,675	1,665	S	y	10	AF	Nugget-Jur	2,720
2	750	580	0		Dakota Morrison	CreU Jur	2,174	2,056	S	y	15	D	Kayenta-Jur	3,045
3	2,250	y	y		Dakota	CreU	5,800	5,700	S	18	40	D	Sundance-Jur	6,790
4	750	320	y		Coconino	Per	3,114	3,093	S	y	21	AF	Kaibab-Per	3,235
5				39	Goodridge	Pen	200	194	S	y	6	S	Hermosa-Pen	3,663
6				34	Kaibab-Moenkopi Cont. (or) upper Kaibab	Tr	665	663	L	y	2	MC	Coconino-Supai-Per	2,195
7														

Oil and Gas Development in West Virginia during 1938

By David B. Reger,* Member A.I.M.E.

(New York Meeting, February, 1939)

Exploration for new pools of gas in the Oriskany sand and continued exploitation of areas already known to be productive in that sand were the main features of petroleum activity in West Virginia during 1938. To a considerable extent the exploration program resulted in failure, but the extension of former areas was eminently successful. Throughout the state, in general, less drilling was done than in 1937. According to the West Virginia Department of Mines, only 631 permits to drill were issued, as compared to 1034 in 1937. The account of operations, as reported by trade journals and other sources, shows that 766 wells were drilled, resulting in 131 oil wells with 1609 bbl. of daily production; 484 gas wells with 1,232,216,000 cu. ft. of daily open flow; and 151 dry holes. Several discoveries indicate new pools of oil and gas; and several extensions of old gas pools have been made. In spite of a decreased number of total wells, the figures for new gas and oil are both larger than in 1937. The new oil average is 12.3 bbl. per well per day; the gas average is 2,545,900 cu. ft. per well per day; the ratio of dry holes to completions is 19.71 per cent.

No general attempt was made to discover new pools of oil. A continued low price, coupled with reduced takings, combined to make drilling unattractive. The principal oil wells completed, by counties are: Boone, 6; Calhoun, 10; Clay, 7; Gilmer, 5; Kanawha, 5; Lincoln, 7; Pleasants, 13; Ritchie, 32; Roane, 6; Tyler, 7; and Wirt, 14. Production for the year, according to the *Oil and Gas Journal*, was 3,724,750 barrels.

The leading counties in gas, with the number of successful wells in each, are: Boone, 16; Braxton, 13; Cabell, 47; Calhoun, 29; Doddridge, 10; Gilmer, 55; Kanawha, 127; Lincoln, 18; Ritchie, 29; Wayne, 19; and Wetzel, 26. Production for the year is estimated as 150,000,000,000 cubic feet.

Pipe-line construction, which was extensive in 1937, was insignificant in 1938. Exploration was not as active as in 1937. Field prices of both oil and gas have severely declined.

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General State of the Industry

Exact figures regarding the amount of land under lease in West Virginia are not available through any public or private agency; an approximation of probable and improbable territory is 4,500,000 acres, with probable territory of 500,000 acres not held by leases. Proved and probable land is estimated at 750,000 acres in oil; 2,500,000 acres in gas. The writer estimates reserves of oil as 90,000,000 bbl. and gas as 7,000,000 million cu. ft. These figures, those on oil in particular, vary considerably from estimates that have from time to time appeared in print. A recent estimate, for instance, gives West Virginia only 9,618,000 bbl. of oil reserve, although production for 1938 is tentatively placed at 3,780,000 bbl. There is, however, abundant evidence to show that such an estimate is entirely too low. As of 1919, the writer made a careful estimate, with the conclusion that 200,000,000 bbl. yet remained. In the years 1920-1938, inclusive, the state has produced 109,312,000 bbl. with a gradual decrease through the years, except that from 1932 to 1938, inclusive, production has been stationary at slightly less than 4,000,000 bbl. per year, reflecting a price that has been generally less than \$2 per barrel. As of 1937, the technicians of a leading producer in West Virginia, using decline figures from 1909 to 1937, inclusive, estimated that the presently productive wells, by presently productive methods, would produce 35,533,590 bbl.; and that the same wells, by repressuring, would produce 81,033,590 bbl. These figures, with a fair allowance for new production, check closely the estimates of the writer.

Up to the end of 1938, there had been completed 62,839 ± oil and gas wells. During the year 131 oil wells and 484 gas wells were completed, and at the end of the year 18,306 ± oil wells and 13,417 ± gas wells were active. Production was approximately:

Period	Oil, Bbl.	Average Oil per Well Daily, Bbl.	Gas, Millions Cu. Ft.	Average Gas per Well per Day, Cu. Ft.
To end of 1938	406,562,000		6,353,458	
During 1937	3,845,000[a]	0.56	149,084[a]	30,992
During 1938	3,725,000[b]	0.57	150,000[c]	30,630

[a] Figures by U. S. Bureau of Mines. [b] Figures by *Oil and Gas Journal*. [c] Estimated.

Principal Areas of Activity

In Barbour County, a small Benson sand (U. Dev.) well, about 2 miles north of Volga, and 3 miles southeast of the territory heretofore recognized as productive in that sand, may point out a considerable area of valuable gas.

In Boone County, 27 wells were drilled, resulting in 6 oil wells with 71 bbl. and 16 gas wells with 4,686,000 cu. ft. of new production.

In Braxton County, a considerable southward extension of the Rosedale gas pool has been proved. The new territory, centering about the village of Sleith, in Birch District, contains about 4000 acres, on which 35 gas wells and 5 dry holes have been drilled. The productive wells are mainly in the Big Injun sand (L. Mis.) but partly in the Salt (L. Pen.) with average open flows of about 400,000 cu. ft. and average rock pressures of about 525 pounds.

In Cabell County, 47 wells out of 49 drilled had gas with 13,134,000 cu. ft. of new production. One well had oil and only one was dry.

In Calhoun County, 10 wells out of 46 had oil with 116 bbl. and 29 had gas with 11,875,000 cu. ft. of new production.

In Clay County, a wildcat well, ½ mile southeast of Villa Nova and adjacent to the Braxton County line, found gas in the Webster Springs sand (U. Mis.) at depth of 1708 to 1758 ft. The well tested 510,000 cu. ft. and 550 lb. rock pressure. An offset has now been started. This production, found in new territory, is also from a new sand not heretofore known as productive. Its stratigraphic position is immediately above the Little Lime (Glenray) and slightly below the Maxton (Droop) sand.

In Gilmer County 55 wells out of 78 drilled had gas with 26,074,000 cu. ft. of new production. Five wells had oil and 18 were dry. The Glenville gas pool, which was very active in 1937, has not proved to be extensive and is now relatively quiet. This pool adjoins the older Stewart Creek territory, not yet wholly drilled, the combined areas being about 10,000 acres.

In Jackson County, as will be discussed later, under the subject of "Development in Oriskany Sand," some new gas was found.

Kanawha County led all others in activity, having 139 wells, mostly Oriskany sand (L. Dev.) gas, as will be hereinafter discussed.

In Lincoln County, besides routine drilling, six Big Lime (L. Mis.) oil wells completed on Guyandot River above Sand Creek, with initial capacities of 25 to 30 bbl. each, after acidizing, gave some promise of a new pool but soon declined to unprofitable figures. Some good brownshale (M. Dev.) wells are reported in the vicinity of Hager and Palermo in Carroll district.

Pleasants County ranked high in the finding of oil, there being 13 new oil wells with 322 bbl. of measured production. This oil was mostly found in an old Big Injun and Squaw sand (L. Mis.) pool astride the Pleasants-Ritchie County line, about 3 miles south of Schultz. A new Big Injun sand (L. Mis.) well, in McKim district north of Maxwell, may open a pool.

Ritchie County led all others in oil. Out of 82 completions 32 wells had oil with 501 bbl.; 29 had gas with 7,425,000 cu. ft. of new production. To a considerable extent the new oil was found in an old pool adjacent to Pleasants County, as above mentioned.

In Wayne County 20 wells were drilled, one of which had oil and the remainder of which had gas, with 8,504,000 cu. ft. of new production. No failures are recorded.

In Wetzel County 26 wells out of 39 completions had gas, with 23,-586,000 cu. ft. of new production. A town-lot development, in the shallow Cow Run sand (Mid. Pen.) at depth of about 600 ft. in the village of Proctor resulted in 20 wells, having average open flows of 500,000 cu. ft. per well and average rock pressures of 150 lb. There is small prospect of any considerable extension. A large well in the Gordon sand (U. Dev.), 2 miles north of Newdale, Proctor district, with an open flow of 10,000,000 cu. ft. and a rock pressure of 1000 lb., may lead to new production in an area where previous production is mainly from the Maxton sand (U. Mis.).

Development in Oriskany Sand

The exploitation of the Oriskany sand (L. Dev.), in which gas was discovered in Kanawha County in 1930 but in which active operation began late in 1934, has proceeded vigorously throughout the year and has now extended into Jackson County. Table 2 shows the scope of Oriskany operations in these two counties. In Jackson County there had been six unsuccessful Oriskany tests before 1938. During 1938 four successful wells were drilled in three magisterial districts and at the end of the year five others were drilling. Three of the new gas wells are adjacent to the productive area of Kanawha County, but the fourth (Brown, 1) is a wildcat in Ravenswood district on the Ohio River just north of Ravenswood city. Although not yet successfully finished, because of lost tools, the well gauged 337,000 cu. ft. and 1600 lb. rock pressure, and may open an entirely new pool. Oriskany exploration in the central portion of Jackson County has not yet been successful.

In Kanawha County, 192 Oriskany wells had been drilled by the end of 1937. Of these, 169 were successful, with a tested open flow of 979,650,000 cu. ft.; and 23 were dry holes. In 1938 there were 120 completions, of which 116 were successful and only 4 were dry. New Oriskany open flow for the 116 gas wells was 1,039,768,000 cu. ft.

The main proved Oriskany territory now consists of portions of Elk, Loudon, Malden, Poca and Union districts of Kanawha County; and portions of Ripley and Washington districts of Jackson County. Three separate pools are recognized. The Campbell-Davis Creek pool is in Loudon and Malden districts southeast of Charleston and astride the Great Kanawha River. The Cooper Creek pool is in Elk district

6 miles northeast of Charleston and on both sides of Elk River. The Elk-Poca pool is in Elk and Poca districts of Kanawha County and in the adjacent portions of Ripley and Washington districts of Jackson County, some miles north of Charleston. In these three pools at the end of 1938 there had been 305 completions, of which 285 were gas wells with a combined initial open flow of 2,019,081,000 cu. ft. and 20 were dry holes. As of Jan. 1, 1939, there were 52 wells drilling or unreported. The average open flow per gas well has been 7,084,494 cu. ft. per day with rock pressures that vary from 1000 to 2000 lb. The present open flow is unknown. The proved territory appears to be about as follows: Campbell-Davis Creek pool, 9085 acres; Cooper Creek pool, 2439 acres; Elk-Poca pool, 51,716 acres; a total of 63,240 acres.

Detailed production figures are not available, but estimates of 150 to 175 billion cu. ft., as of the end of 1938, are current. Comprehensive estimates of reserves are also lacking because no single organization appears to be in possession of all the data on rock pressure and production. It is believed, however, that unit production may somewhat exceed 5,000,000 cu. ft. per acre. Using this figure as the minimum, the ultimate recovery, including gas already taken out, would be 316,400,000,000 cu. ft. At the present time, practically all the gas is under contract, but it is estimated that only about 20 per cent of the available supply is being produced, because pipe lines and markets are not available to handle it.

Within recent weeks 10 new wells in the northern edge of Poca district have been shut in because of the appearance of sour gas. The objectionable matter in these wells, consisting of hydrogen sulphide plus mercaptans, is reported as 50 grains per 100 cu. ft. A correction plant may or may not be required to handle these and other possible sour wells.

In other counties, outside of Jackson and Kanawha, exploration in the Oriskany sand has shown poor results. Various tests in Boone, with the exception of one small well, have been failures. No Oriskany gas has yet been found in Cabell, Calhoun, Clay, Doddridge, Fayette, Hancock, Lincoln, Logan, McDowell, Marion, Mason, Mingo, Putnam, Randolph, Roane, Wayne and Wirt, although one or more tests have been made in each of these counties. In Wood there have been several tests, one of which had gas in some quantity. In Monongalia the prospect appears rather good for production in the Huntersville chert, which is of Oriskany age, immediately overlying the sand proper. This chert now produces from three wells on the Chestnut Ridge anticline in Fayette County, Pa., 10 miles north of the Monongalia line; and another well, 1 mile north of the same line, is showing for a producer, but its completion has been delayed by lost tools (recovered as of Jan. 23). The same anticline extends across Monongalia County, and nearly all of the avail-

TABLE 1.—*Important Wildcats Drilled in West Virginia during* 1938

No.	County	Magisterial District	Location Lat.	Location Long.	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Property and Well No.	Initial Production per Day Oil, Bbl.	Initial Production per Day Gas, M Cu. Ft.	Tubing Pressure, Lb. per Sq. In.	Remarks
1	Barbour	Union	4.72 mi. S. of 39° 10′	2.97 mi. W. of 80° 05′	4,417	Pen.-Conemaugh	U. Dev.-Benson	Hope Nat. Gas Co.	Indian Fork C. & C. Co., 1-7800	0	104		Benson gas well; R.P. 175 lb. in 60 min.
2	Boone	Scott	1.07 mi. S. of 38° 10′	0.63 mi. E. of 81° 50′	4,442	Pen.-Kanawha	L. Dev.-Oriskany	Sayre Oil & Gas Co.	Scott Pickens, 3	0			Dry in Oriskany; Berea gas well
3	Boone	Sherman	3.92 mi. S. of 38° 10′	3.3 mi. W. of 81° 35′	5,457	Pen.-Kanawha	M. Dev.-Corniferous	Columbian Carbon Co.	R. H. Wood, 3-280	0	252	180	Brown-shale gas well
4	Boone	Sherman	3.6 mi. S. of 38° 10′	3.0 mi. W. of 81° 35′	5,444	Pen.-Kanawha	L. Dev.-Oriskany	Columbian Carbon Co.	R. H. Wood, 4-285	0	73	165	Brown-shale gas well
5	Boone	Washington	3.13 mi. N. of 38° 00′	1.98 mi. W. of 81° 50′	4,383	Pen.-Kanawha	L. Dev.-Oriskany	Hope Nat. Gas Co.	Julian Hill, 1-7812	0	62	320	Dry in all sands below Berea; gas in Big Lime, Big Injun and Berea
6	Boone	Washington	3.13 mi. N. of 37° 55′	0.47 mi. E. of 81° 30′	2,480	Pen.-Kanawha	L. Mis.-Berea	Hope Nat. Gas Co.	H. Nunnencamp, 7726	10	2,500	190 (1 hr.)	Berea oil and gas well
7	Clay	Buffalo	0.36 mi. S. of 38° 35′	0.67 mi. W. of 79° 55′	1,758	Pen.-Conemaugh	U. Mis.-Webster Springs	Pittsburgh & W. Va. Gas Co.	E. L. Boggs, 1-7662	0	510	550	Webster Springs gas well
8	Clay	Otter	3.00 mi. S. of 38° 40′	0.23 mi. E. of 81° 00′	6,451	Pen.-Conemaugh	L. Dev.-Oriskany	Pittsburgh & W. Va. Gas Co.	Jessie Chapman, 1-7644	0	416	325	Dry in Oriskany; Third Salt gas well
9	Jackson	Ravenswood	0.83 mi. S. of 38° 55′	0.92 mi. W. of 81° 40′	4,715	Perm.-Dunkard	L. Dev.-Oriskany	W. H. Pettry	D. O. Curry, 1	0	20		Oriskany gas show, 20 M cu. ft.; lost tools and abandoned
10	Jackson	Ravenswood	3.48 mi. S. of 38° 45′	1.01 mi. W. of 81° 45′	4,300	Perm.-Dunkard	L. Dev.-Oriskany	Joe Rubin	W. J. Brown, 1	0	337	1,600	Oriskany gas well
11	Jackson	Ripley	0.9 mi. S. of 38° 35′	2.27 mi. W. of 81° 35′	4,950	Pen.-Monongahela	L. Dev.-Oriskany	Cunningham Gas Co.	E. F. Cunningham, 1	0	3,500		Oriskany gas well
12	Jackson	Ripley	1.90 mi. S. of 38° 50′	1.28 mi. W. of 81° 40′	5,000	Perm.-Dunkard	L. Dev.-Oriskany	Potter Dev. Co.	W. T. Chancey, 1	0	0	0	Dry hole
13	Jackson	Ripley	4.67 mi. S. of 38° 40′	3.3 mi. W. of 81° 35′	5,054	Pen.-Monongahela	L. Dev.-Oriskany	E. Starcher et al.	Story Boggess, 1	0	7,647	1,880	Oriskany gas well
14	Jackson	Washington	0.35 mi. S. of 38° 35′	4.44 mi. W. of 81° 30′	5,272	Pen.-Monongahela	L. Dev.-Oriskany	United Carbon Co.	E. W. Perkins, 3	0	5,329	1,800	Oriskany gas well
15	Kanawha	Elk	0.36 mi. S. of 38° 20′	2.75 mi. W. of 81° 20′	4,000	Pen.-Conemaugh	U. Dev.-Portage	Cameron O. & G. Co.	Henry Hansell, 1	0	400		Squaw gas at 2240′
16	Kanawha	Elk	0.02 mi. N. of 38° 30′	0.03 mi. E. of 81° 30′	5,259	Pen.-Conemaugh	L. Dev.-Oriskany	Everett Starcher	W. M. Drake, 2	0	1,500		Oriskany gas well
17	Kanawha	Malden	0.15 mi. S. of 38° 20′	2.60 mi. E. of 81° 30′	4,930	Pen.-Kanawha	L. Dev.-Oriskany	North Eight Prod. Co.	L. E. & R. Belcher, 1-4	0	0	0	Dry hole

TABLE 1.—(*Continued*)

No.	County	Magisterial District	Location: Lat.	Location: Long.	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Property and Well No.	Initial Production per Day: Oil, Bbl.	Initial Production per Day: Gas, M Cu. Ft.	Tubing Pressure, Lb. per Sq. In.	Remarks
18	Kanawha	Washington	0.02 mi. N. of 38° 20′	0.03 mi. E. of 81° 50′	4,520	Pen.-Conemaugh	L. Dev.-Oriskany	Owens-Libbey-Owens Gas Dept.	Garnett Wiseman, 1-551	0	80		Dry in Oriskany; Brown shale gas well
19	Logan	Logan	2.22 mi. S. of 37° 55′	1.20 mi. W. of 82° 00′	3,814	Pen.-Kanawha	M. Dev.-Hamilton	Hope Nat. Gas Co.	A. Lawson Hrs., 1-7823	0	0	0	Dry hole in Brown shale
20	Pleasants	McKim	4.26 mi. S. of 39° 25′	2.00 mi. W. of 81° 05′	1,895	Perm.-Dunkard	L. Mis.-Big Injun	Hart Oil Co.	Raymond Hart, 1	30	765		Big Injun oil and gas well
21	Putnam	Teays Valley	2.68 mi. S. of 38° 30′	2.27 mi. W. of 82° 00′	4,152	Pen.-Conemaugh	L. Dev.-Oriskany	Teavee O. & G. Co.	W. C. Swann, 1	0	0	0	Dry hole
22	Upshur	Banks	1.95 mi. S. of 38° 50′	1.95 mi. W. of 81° 15′		Pen.-Kanawha		Paul Weekley	E. J. Smallridge, 1 (C. Rice)	0			Gas well; no record
23	Wetzel	Proctor	2.28 mi. N. of 39° 40′	2.03 mi. W. of 80° 40′	3,016	Perm.-Dunkard	U. Dev.-Gordon	Manufacturers L. & H. Co.	Elizabeth Blatt, 1-3562	0	10,000	1,000	Gordon gas well
24	Wirt	Newark	0.54 mi. N. of 39° 05′	2.2 mi. W. of 81° 20′	3,405	Perm.-Dunkard	U. Dev.-Benson?	T. C. Exline	T. C. Exline, 3	0	0	0	Dry hole
25	Wirt	Tucker	2.83 mi. S. of 39° 05′	1.09 mi. W. of 81° 30′	5,518	Perm.-Dunkard	L. Dev.-Oriskany	Roberts Bros. & Carnegie N. G. Co.	W. O. Caplinger, 1-1524	0	0	0	Dry hole
26	Wood	Lubeck	0.38 mi. S. of 39° 15′	0.17 mi. W. of 81° 35′	4,470	Perm.-Dunkard	L. Dev.-Oriskany	W. H. Bickel	W. H. Bickel, 1	0	100	600	Dry in Oriskany; Brown shale gas well, drilled deeper
27	Wood	Steele	5.45 mi. S. of 39° 10′	4.4 mi. W. of 81° 30′	5,220	Perm.-Dunkard	L. Dev.-Oriskany	Belmont Quad. Drilling Co.	C. D. White, 1	0	0	0	Dry hole

able territory is under lease. Table 1 shows the result of wildcat drilling, mainly to the Oriskany sand, throughout the state in 1938. Table 2 gives the details of Oriskany drilling in Jackson and Kanawha Counties.

TABLE 2.—*Oriskany Sand Wells, Jackson and Kanawha Counties, W. Va.*

County and Magisterial District	Completed before 1938				Completed in 1938				Total Number of Wells	Number of Wells Drilling or Unreported Jan. 1, 1939
	Gas Wells		Dry in Oriskany	Total Number of Wells	Gas Wells		Dry in Oriskany	Total Number of Wells		
	Number of Wells	Gas, M Cu. Ft.			Number of Wells	Gas, M Cu. Ft.				
Jackson County.:										
Grant	0	0	0	0	0	0	0	0	0	0
Ravenswood	1	0	1	2	1	337	0	1	3	0
Ripley	0	0	0	0	2	11,155	0	2	2	3
Union	0	0	0	0	0	0	0	0	0	0
Washington	2	0	2	4	1	5,329	0	1	5	2
Total	3	0	3	6	4	16,821	0	4	10	5
Kanawha County.:										
Big Sandy	0	0	1	1	0	0	0	0	1	0
Cabin Creek	0	0	3	3	0	0	0	0	3	0
Charleston	0	0	1	1	0	0	0	0	1	0
Elk	66	296,240	8	74[a]	16	35,998	1	17	91	8
Jefferson	0	0	1	1	0	0	0	0	1	0
Loudon	7	2,703	5	12	0	0	0	0	12	0
Malden	33	69,300	4	37	2	1,747	1	3	40	6
Poca	58	605,502	0	58	92	986,976	1	93	151	37
Union	5	5,905	0	5	6	15,047	0	6	11	2
Washington	0	0	0	0	0	0	1	1	1	0
Total	169	979,650	23	192	116	1,039,768	4	120	312	53
Grand total	172	979,650	26	198	120	1,056,589	4	124	322	58

[a] Includes one oil well completed in 1934 with 158 bbl. daily production.

OPERATING TECHNOLOGY

Routine methods of operating oil and gas wells are mainly followed. Rotary drilling has not yet been tried in the state, although three or four extremely deep wells have now been completed by this method in Pennsylvania. In Kanawha County many of the Oriskany gas wells are now being completed with a Spang drilling-in-head, which is attached to a flange above the master gate and which prevents any serious flow of gas into the derrick.

A considerable amount of gas from new operations is now being moved to favorably situated old wells in Harrison, Lewis and Taylor Counties for underground storage. Also, a very large quantity of Oriskany gas has been moved to central Ohio for storage in old Clinton sand wells.

Pipe Lines and Markets

Pipe-line building in 1938 was mainly confined to small extensions. In Kanawha County the West Virginia Gas Corporation built 6 miles of 8-in. gas line from its operations on Grapevine Creek, Poca district, eastward to Hunt station. In Boone County, Owens-Libbey-Owens Gas Department built 6 miles of 10-in. gas line from its Brushton compressor northwestward to Longshoal run, to pick up both produced and purchased shale gas. In Cabell County, Clayco Gas Co. is building a new line from Salt Creek on Guyandot River southwestward 5 or 6 miles to Bowen Creek.

For several months in the latter part of 1938 the price of oil was only $1.28 per barrel, coupled with a 25 per cent restriction on production. In January 1939, the price was raised to $1.37 and restriction of output was removed as of Feb. 1. Even with these more favorable conditions there will be small profit, if any, from oil operations in West Virginia.

The field, or well-mouth, price of gas has steadily declined for several years. Starting with the maximum of 18.9¢ per M cu. ft. in 1931, the U. S. Bureau of Mines figures are: 1932, 18.5¢; 1933, 18.0¢; 1934, 17.6¢; 1935, 16.9¢; 1936, 14.8¢; 1937, 12.9¢; 1938, not yet reported. A West Virginia operator can hardly get more than 12¢ per 1000 at present and must, of course, be content with a three or four-month summer shut-in, because of reduced demand in that period of the year. Most of the gas produced by independents is under a contract of some sort, but it would be difficult to determine, or even estimate, the amount of gas that might be produced annually if there were a full demand during the winter months. It is believed, however, that the state could supply an annual demand of considerably more than 200,000,000 M cu. ft., and could at the same time meet all peak loads that would accompany such a demand.

County Summary

Table 3 shows by counties the new development in West Virginia during 1938. This information was mainly gathered from trade journals and private reports. The summary of completions is not necessarily the same as that published annually by the West Virginia Department of Mines, because of the lag occurring between completion dates and reports to the Department. There is no full comparison for initial well capacities, because there is no legal requirement for reporting these to any public agency. In many cases, however, the figures for open flow and rock pressure are voluntarily reported to the Department. In such cases the operators are entitled to many thanks.

TABLE 3.—*Summary of New Development in West Virginia during* 1938

County	Number of Wells Drilled	Oil Wells		Gas Wells		Dry Holes
		Number of Wells	Bbl. per Day	Number of Wells	M Cu. Ft. per Day	
Barbour	1	0	0	1	75	0
Boone	27	6	71	16	4,686	5
Braxton	15	0	0	13	3,445	2
Brooke	3	1	1	0	0	2
Cabell	49	1	2	47	13,134	1
Calhoun	46	10	116	29	11,875	7
Clay	17	7	107	7	2,880	3
Doddridge	15	2	8	10	3,118	3
Fayette	1	0	0	0	0	1
Gilmer	78	5	37	55	26,074	18
Hancock	8	3	9	3	300	2
Harrison	11	1	5	8	1,480	2
Jackson	8	0	0	4	16,833	4
Kanawha	139	5	39	127	1,058,689	7
Lewis	8	1	15	6	1,273	1
Lincoln	26	7	86	18	3,050	1
Logan	6	0	0	5	3,362	1
Marion	6	0	0	3	943	3
Marshall	9	1	5	5	2,225	3
Mason	1	0	0	1	156	0
Mingo	4	0	0	4	13,719	0
Monongalia	13	3	13	9	1,467	1
Nicholas	6	0	0	3	1,774	3
Pleasants	33	13	322	6	1,514	14
Putnam	9	0	0	9	6,770	0
Ritchie	82	32	501	29	7,425	21
Roane	22	6	126	6	2,592	10
Tyler	16	7	50	2	140	7
Upshur	4	0	0	3	1,330	1
Wayne	20	1	6	19	8,504	0
Wetzel	39	1	30	26	23,586	12
Wirt	30	14	44	9	9,705	7
Wood	14	4	16	1	92	9
State total	766	131	1,609	484	1,232,216	151

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Oil and Gas Development in Wyoming in 1938

By C. E. Shoenfelt,* Member A.I.M.E., and E. W. Krampert†

The major oil discovery in 1938 for Wyoming was the General Petroleum Corporation's No. 1 Government, C.NW.SE. of sec. 21-35N-77W, on the Cole Creek structure in central Wyoming, 14 miles northeast of Casper. This well found commercial oil production in basal Cloverly sand (Lakota) at 7978 ft. and was completed on May 28, 1938, at 8019 ft., 3 ft. in Morrison shale. It had an initial production of 10 bbl. of oil an hour but at the end of a 7-day test made 336 bbl. of oil in 24 hr. During 1938, the well produced a total of 23,161 bbl. of oil. It has been agitated about 10 days out of each month to provide fuel for lease and drilling operations, the balance of the time it has been shut in pending the completion of the second well on the structure. The Cole Creek oil is of intermediate base and has an A.P.I. gravity of 32.7°. The record of the well contains the "tops" listed in the accompanying tabulation.

Tops in General Petroleum Corporation's No. 1 *Government Well*

Feet	
2240	Top of the Mesa Verde (Teapot sandstone)
2960	Top Steele shale
4500	Shannon sand; good show of oil and gas
6740	Top Frontier sand; some oil saturation
6840	Halliburton test of Frontier did not show much oil, but at 6878 ft. the oil showing amounted to 50 barrels
6878–7051	Shale
7051–7062	Sand with some oil saturation
7062–7920	Shale (sandy phase of Thermopolis shale 7779 to 7788 ft.)
7920–7926	Sand (Muddy); oil-saturated
7926–7974	Shale
7974–7979	Hard, coarse, limy sand (Dakota); some oil saturation
7979–7997	Soft sand; high oil saturation
7997–8002	Shale with pyrites
8002–8016	Sand (Lakota)
8016–8019	Variegated Morrison shale
5600	Elevation

Lance Creek Field.—Important extensions to the Lance Creek field in eastern Wyoming were made in 1938 by the completion of a number of

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prolific Minnelusa sand producers on the southwest and the north sides of the field, well outside of the limits of the Sundance sand area. The Minnelusa sand referred to is the second sand in the Minnelusa formation of Pennsylvanian age, and is known locally as the "Leo pay."

There were 27 completions in the Lance Creek field in 1938, of which 18 were Leo sand oil wells; six were Sundance sand oil wells; one was a Leo sand gas well; one a Leo sand dry hole, and one a Dakota sand dry hole. Initial new production for the Leo sand was 26,112 bbl. and for the Sundance sand 4757 bbl. Initial gas production from the Leo sand was 2,723,000 cubic feet.

As a result of the wells completed last year, the productive area of the field is limited on the west by a dry hole completed by J. E. Manning and associates, on the Peklo farm in the SE.SE.SE. of sec. 1-35N-66W. The southeast side of the field is limited by a dry hole drilled in 1937 on the Taylor permit in sec. 3-35N-65W, and by No. 1 on Leo 7 in sec. 35-36N-65W, which was completed as a small pumper in 1937. The limits of the north and east sides of the field are not so clearly defined.

Oil Springs Anticline.—Gas was discovered on June 29, 1938, in the Oil Springs anticline, by The Cunningham Oil Co., in Sundance sand at 2225 to 2350 ft. The discovery well is on Union Pacific R.R. lands in sec. 3-23N-79W, and the field was developed further in 1938 by The Ohio Oil Co. with the completion late in the year of an offset well on its Baker permit in sec. 2. Gas from the new field will be utilized for repressuring operations in some of the Laramie Basin oil fields and will augment the gas reserves for the towns served by the Rocky Mountain Gas Company's lines from Allen Lake field to Laramie, Wyoming.

The discovery well had its first showing of gas at 2225 ft., in the top of the Sundance sand, and the well gauged 3,880,000 cu. ft. of gas under 900 lb. pressure at 2267 ft. It gauged 9,500,000 cu. ft. of gas in sand at 2267 to 2287 ft., and the final gauge at 2287 to 2315 ft., was 11,200,000 cu. ft., under 1200 lb. pressure.

The offset well of The Ohio Oil Co. was completed in December at 2353 ft., and gauged initially 20,000,000 cu. ft. of gas under 1110 lb. pressure.

The Oil Springs anticline is a very sharp fold formed in beds of Upper Cretaceous age. The oldest exposed rocks belong to the Frontier formation, the lower sand of which produces gas in small quantities at shallow depths.

Beaver Creek Dome.—The Beaver Creek dome in Fremont County was proved for gas by the completion of Stanolind Oil & Gas Company's No. 1 Elton D. Johnson well on the C.SE.SE. of sec. 3-33N-96W. This well was started in 1937 and completed on June 3, 1938, for 9,000,000 cu. ft. of gas in Morrison sand at 8244 to 8288 ft. after plugging back from a total depth of 8920 ft. The Sundance sand, final objective of the test, was dry. No market for gas from this field is immediately available,

TABLE 1.—*Oil and Gas Production in Wyoming in 1938*

C, Complete Data Inc, Incom. Data	Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres: Oil	Area Proved, Acres: Gas[a]	Total Oil Production, Bbl.: To End of 1938	Total Oil Production, Bbl.: During 1938
C	1	Alkali Butte, *Fremont*	10	40	300	8,130	0
C	2	Allen Lake, *Carbon*	5	0	200		
C	3	Ant Hills, *Niobrara*	11	40		7,378	0
C	4	Badger Basin, *Park*	8	300		211,943	55,720
C		Baxter Basin (South), *Sweetwater:*					
	5	Frontier	16		7,467		
	6	Dakota	16		4,310		
C		Baxter Basin (North), *Sweetwater:*					
	7	Dakota	12	0	1,280		
	8	Sundance	10	0	2,280		
C	9	Beaver Creek, *Fremont*	1		640		
		Big Muddy, *Converse:*	22				
	10	Shannon	22	2,000			
	11	Wall Creek	22			25,696,331	441,082
	12	Dakota	16				
C		Big Sand Draw, *Fremont:*					
	13	Wall Creek	21		1,200		
	14	Lakota	8		300		
C	15	Billy Creek, *Johnson*	17		1,200		
C	16	Black Mountain, *Hot Springs*	15	300	300	251,998	46,255
C		Bolton Creek, *Natrona:*					
C	17	Sundance	18	50		51,210	875
C	18	Embar	18	50			875
C	19	Boone Dome, *Natrona*	18		300		
C	20	Bunker Hill, *Carbon*	2		480		
C		Byron Dome, *Big Horn:*					
C	21	Frontier	16	0	500		
C	22	Sundance	9	40	0	14,000	0
C	23	Embar-Tensleep	6	2,950	0	1,718,117	539,014
C	24	Cole Creek, *Natrona*	1	*x*		23,161	23,161
C	25	Dallas-Derby, *Fremont*	55	350	0	2,656,565	157,127
C	26	Dewey Dome, *Weston*	2	40	0	3,208	2,405
C		Dutton Creek, *Carbon:*					
C	27	Shannon	12	0	800		
C	28	Muddy	12	150	0	235,792	17,654
C	29	East Allen Lake, *Carbon*	2		410		
C	30	East Lance Creek, *Niobrara*	20	400	150	449,000	9,000
C	31	Eight Mile Lake, *Carbon*	15		250		
C		Elk Basin, *Park:*					
C	32	Frontier	23	580		10,759,351	99,585
C	33	Dakota	17		1,200		
C	34	Enos Creek, *Hot Springs*	15		500		
C	35	Ferris, *Carbon*	21	200	200	486,669	2,268
C		Ferris (West), *Carbon:*					
C	36	Dakota	17		3,100		
C	37	Sundance	13		3,500		
C	38	Fourbear, *Park*	10	500			
C		Frannie, *Park:*					
C	39	Tensleep	10	500		2,841,894	523,705
C	40	Madison	9	10		93,952	6,879
C		Garland, *Big Horn-Park:*					
C	41	Frontier	31	40	1,000	342,700	0
C	42	Dakota	19	0	1,200		0
C	43	Embar-Tensleep	11	160	1,650		0
C	44	Madison	7	2,000	500		778,621
C	45	Golden Eagle, *Hot Springs*	19		120		
C	46	Gooseberry, *Park*	2	500		1,696	0
C		Grass Creek, *Hot Springs:*					
C	47	Frontier	24	1,400		24,587,271	323,361
C	48	Embar-Tensleep	17	2,000		1,924,911	186,484
C	49	Greybull, *Big Horn*	30	640	160	245,362	150
C	50	Hamilton, *Hot Springs*	20	2,000		4,791,545	253,044
C	51	Hidden Dome, *Washakie*	21	50	640	283,812	40,613
C	52	Iron Creek, *Natrona*	16	80	80	16,257	5,267
C	53	La Barge, *Lincoln-Sublette*	15	950		5,465,785	354,645
C	54	Lake Creek, *Hot Springs*	13	100		5,000	0
C		Lance Creek, *Niobrara:*					
C	55	Dakota	23	1,000	3,500	4,414,553	30,000
C	56	Sundance	8	1,700	0	9,451,879	2,825,919
C	57	Minnelusa	2	15,000	0	1,833,556	1,717,449
C	58	Lander (Hudson), *Fremont*	20	340		1,964,412	95,517
C	59	Little Buffalo Basin, *Park*	24		4,800		
C	60	Little Grass Creek, *Hot Springs*		0	300		
C	61	Little Pole Cat, *Park*	20		500		

[a] Footnotes to column heads and explanation of symbols are given on page 240.

TABLE 1.—(*Continued*)

	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					Oil Production Method at End of 1938			Pressure, Lb. per Sq. Inch[d]		
				During 1938		At End of 1938		Number of Wells				Average at End of	
Line Number	To End of 1938	During 1938	Completed to End 1938	Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Flowing	Pumping	Air, Gas, Lift, Water	Initial	1937	1938
1	0	0	3	0	0	0	3	0			*y*	*y*	*y*
2	819	40	7	0	1	0	4				920	*y*	450
3			2	0	0	0	0	0	0	0	*x*	*x*	*x*
4			4	1	0	4	0	4	0	0	*y*	*y*	*y*
5			13			0	12				800		
6	18,062	5,860	11			0	11				815		
7			3			0	3				1,335	1,080	
8			2			0	2				1,485	1,080	
9	0	0	1	1	0	0	1				2,500		2,500
10			35	0	0	10		0	10	0			
11			134	0	0	134	0	0	134	0			
12			5	0	0	5	0	0	5	0			
13	50,695	4,210	10	0	0	0	10				1,300	750	680
14			1	0	0	0	1				1,860	1,860	
15	2,704	311	9	0	0	0	8				1,150	710	400
16			6	0	0	6	0	0	6	0	*x*	*x*	*x*
17			8	0	0	2	0	0	2	0	*x*		
18			6	0	0	1	0	0	1	0	*x*		
19	4,072	1	4	0	0	0	2				750	200	180
20	0	0	5	0	0	0	2				500	500	500
21	3,378	225	2	0	0	0	2		0	0	1,000	370	350
22	0	0	1	0	0	0	0	0	0	0	*x*	*x*	*x*
23	0	0	15	0	0	15	0	0	15	0	*x*	*x*	*x*
24			2	2	1	1	0	1	0	0			
25			72	0	0	42	0	0	42	0	*x*	*x*	*x*
26			3	1	1	1	0	0	1	0	*x*	*x*	*x*
27	1,190	100	5	0	0	0	5				440	310	295
28			3	0	0	3	0	0	3	0			
29	15	15	2	0	0	0	2				1,050	1,050	1,000
30	0	0	3	0	0	1	1	0	1		*y*	*y*	*y*
31	4,870	0	4	0	0	0	1				1,724	600	600
32			149	0	0	142	0		142	0			
33	24,419	1,650	9	3	2		7				925	523	498
34			3	0	0	0	1				750	730	730
35	*y*	0	25	0	0	25	0		8		1,020	125	*y*
36	8,040	0	2	0	0	0	2				1,000	200	168
37	16,692	553	11	0	0	0	11				1,140	200	168
38			1	0	0	1	0		1				
39			13	1	0	12	0	0	12	0			
40			2	0	0	1	0	1	0	0			
41	590	29[a]	50	0	0	0	4				*x*	*y*	*y*
42	20,469[a]	50[a]	10	0	0	0	3				745	150	145
43	21,245[a]	617[a]	1	0	0	0	1				1,470	1,110	1,260
44	911[a]	148[a]	14	1	0	13	0	12	1	0	1,600	1,110	1,260
45	2,250	Exh.	3	0	0	0	0				1,175		Exh.
46			3	0	0	1	0	0	1	0			
47			316	0	0	316	0		316				
48			15	0	0	15	0		15				
49	*x*		14	0	0	3	0		3		*x*		Exh.
50			35	2	0	33	0		33				
51	27,000	0	30	2	2	15	6	0	15		725	Exh.	Exh.
52	*y*	0	5	0	0	1	0	0	1	0	200		Exh.
53			115	2	0	95	0	0	95				
54			3	0	0	1	0	0	1				
55	59,800	0	78	0	0	1	12	0	1	0	910		
56	3,842	0	63	12	4	56	0	52	4	0	1,600		
57	0	0	32	19	1	30	0	30	0	0	2,000		
58			36	0	0	11	0	0	11	0			
59	17,371	1,523	10	0	0	0	8				600	395	393
60	*x*	84	2	0	0	0	2				1,140		400
61	913	76	1	0	0	0	1				1,375	1,114	1,090

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1938. Gravity A.P.I. of 60° F. Weighted Average	Producing Formation								Deepest Zone Tested	
		Name	Age[e]	Depth Average in Feet: Bottoms of Productive Wells	Depth Average in Feet: Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness Ave. in Ft.	Structure[h]	Name	Depth of Hole, Ft.
1	36	Morrison	Jur	4,600	4,570	S	Por	30	A	Chugwater	5,460
2		Sundance	Jur	2,175	2,100	S	Por	40	A	Chugwater	4,083
3	36	Dakota	CreU	3,957	3,951	S	Por	6	A	Lakota	4,257
4	48	Frontier	CreU	8,500	8,250	S	Por	49	A		
5		Frontier	CreU	2,400	2,200	S	Por	16	AF	Nugget	3,822
6		Dakota	CreU	3,500	3,000	S	Por	50	AF		
7		Dakota	CreU	3,100	2,950	S	Por	20	AF	Chugwater	4,200
8		Sundance	Jur	3,400	3,350	S	Por	15	AF		
9		Lakota	CreU	8,288	8,244	S	Por	44	A	Sundance	8,920
10	31	Shannon	CreU	1,250	1,200	S	Por	65	A		
11	33	Wall Creek	CreU	3,400	3,260	S	Por	100	A	Madison	6,597
12	33	Dakota	CreU	4,700	4,600	S	Por	15	A		
13		Wall Creek	CreU	2,800	2,300	S	Por	150	A	Sundance	5,345
14		Lakota	CreL	4,350	4,300	S	Por	40	A		
15		Wall Creek	CreU	3,250	3,200	SH	Por	20	A	BigHornLime	7,775
16	24	Embar-Tensleep	Per, Pen	3,350	2,900	LS	Cav, Por	135	A	Madison	3,832
17	22	Sundance	Jur	1,120	1,015	S	Por	10	AF	Amsden	2,867
18	32	Embar	Per	2,050	2,025	L	Cav	15	AF		
19		Shannon	CreU	2,200	2,150	S	Por	70	A	Niobrara	5,200
20		Shannon	CreU	1,480	1,224	S	Por	250	A	Sundance	6,791
21		Frontier	CreU	2,500	2,400	S	Por	30	A		
22	32	Sundance	Jur	4,209	4,205	S	Por	4	A	Amsden	6,700
23	25	Embar-Tensleep	Per, Pen	5,700	5,300	LS	Cav, Por	130	A		
24	32.5	Lakota	CreL	8,019		S	Por		A	Sundance	8,707
25	23	Embar-Tensleep	Per, Pen	1,200	700	LS	Cav, Por	150	A	Tensleep	1,400
26	31	Leo Sand	Pen	2,349	2,294	S	Por	40	H	Minnelusa	2,505
27		Shannon	CreU	1,700	1,600	S	Por	40	A	Sundance	5,488
28	34	Muddy	CreU	4,900	4,850	S	Por	30	A		
29		Sundance	Jur	2,088	2,000	S	Por	48	A	Sundance	2,180
30	42	Dakota	CreU	4,008	3,808	S	Por	95	A	Madison	6,434
31		Dakota	CreU	3,500	3,400	S	Por	50	A	Chugwater	4,560
32	43	Frontier	CreU	1,200	1,000	S	Por	40	Af	Morrison	3,223
33		Dakota	CreU	2,500	2,400	S	Por	55	Af		
34		Frontier	CreU	2,850	2,600	S	Por	40	A	Dakota	3,992
35	36	Mowry-Dakota	CreU	1,650	1,600	S	Por	25	A	Embar	4,600
36		Dakota	CreU	2,300	2,200	S	Por	30	A	Tensleep	4,690
37		Sundance	Jur	2,700	2,600	S	Por	110	A		
38	15	Tensleep	Pen	3,350	3,270	S	Por	60	A	Tensleep	3,350
39	28	Tensleep	Pen	3,530	2,770	S	Por	100	AF	Madison	3,230
40	18	Madison	Mis	3,013	3,012	L	Cav	1	AF		
41	42	Frontier	CreU	900	700	S	Por	35	Af		
42		Dakota	CreU	1,600	1,500	S	Por	50	Af	Cambrian	4,750
43	19	Embar-Tensleep	Per, Pen	4,275	3,000	LS	Cav, Por	100	A		
44	19	Madison	Mis	4,726	3,600	L	Por, Cav	300	A		
45		Mesaverde	CreU	3,000	2,250	S	Por	50	A	Cody	4,019
46	22	Embar-Tensleep	Per, Pen	6,049	5,669	LS	Cav, Por	50	A	Tensleep	6,076
47	44	Frontier	CreU	1,200	800	S	Por	250	A	Amsden	4,335
48	23	Embar-Tensleep	Per, Pen	4,000	3,600	LS	Cav, Por	200	A		
49	48	Greybull	CreU	1,050	1,000	S	Por	20	AF	Tensleep	2,950
50	23	Embar-Tensleep	Per, Pen	3,332	2,700	LS	Cav, Por	130	A	Tensleep	2,886
51	47	Frontier	CreU	1,600	1,200	S	Por	15	A	Greybull	2,785
52	32	Dakota	CreU	820	650	S	Por	25	A	Sundance	1,633
53	31	Wasatch	Eoc	1,000	650	S	Por	150	Af	Hilliard	6,200
54	26	Embar	Per	3,760	3,730	L	Cav	30	A	Tensleep	3,830
55	42	Dakota	CreU	3,665	2,820	S	Por	65	A		
56	44	Sundance	Jur	4,100	3,500	S	Por	65	A	Granite	6,434
57	44	Leo	Pen	5,630	4,900	S	Por	60	A		
58	23	Embar Tensleep	Per, Pen	2,750	1,300	LS	Cav, Por	185	A	Tensleep	2,190
59		Frontier	CreU	1,500	1,200	S	Por	100	A	Mowry	1,670
60		Frontier	CreU	2,901	2,665	S	Por		A	Frontier	2,901
61		Frontier	CreU	4,100	3,900	S	Por	15	A	Cloverly	5,660

TABLE 1.—(*Continued*)

C, Complete Data Inc, Incom. Data	Line Number	Field, *County*	Age, Years to End of 1938	Area Proved, Acres		Total Oil Production, Bbl.	
				Oil	Gas[a]	To End of 1938	During 1938
C		Lost Soldier, *Sweetwater:*					
C	62	Frontier	22	160	0	2,088,045	7,172
C	63	Dakota-Lakota	19	450	0	11,605,847	109,640
C	64	Sundance	12	160	0	5,003,728	253,982
C	65	Tensleep	8	160	0	801,032	230,143
C		Mahoney Dome, *Carbon:*					
Inc	66	Dakota	19	0	1,400	800	
Inc	67	Sundance	14	0	1,660	0	
C	68	Tensleep	9	250	0	27,922	26,422
C	69	Maverick Springs, *Fremont*	21	1,400		0	0
C	71	Medicine Bow, *Carbon*	4	800	320	2,681,174	1,132,723
C	72	Midway, *Natrona*	8	200	0	186,934	11,317
C		Mule Creek (East), *Niobrara:*					
C	73	Lakota	18	220	0	1,241,949	41,123
C	74	Minnelusa	8	100	0	3,750	0
C	75	Mule Creek (West), *Niobrara:*					
C	76	Dakota-Lakota	9	170	0	44,525	4,875
C	77	Minnelusa	7	400	0		3,650
C		Muskrat, *Fremont:*					
C	78	Frontier	11	0	500		
C	79	Dakota	2				
C	80	North Casper Creek, *Natrona*	7	100	0	1,874	0
C	81	North Garland (Danker), *Park*	23	0	800		
C	82	North Sunshine, *Park*	11	150	0	0	0
C	83	Notches, *Natrona*	16	400	0	170,000	0
C	84	Oil Springs, *Carbon*		0	160		
C		Oregon Basin, *Park:*					
C	85	Dakota	26	0	1,300		
C	86	Embar-Tensleep	12	10,000	0	9,647,393	1,019,246
C	87	Osage, *Weston*	18	10,000	0	4,233,477	294,052
C		Pilot Butte, *Fremont:*					
C	88	Niobrara	22	250	0	549,120	7,291
C	89	Muddy	9	0	400		
C	90	Pitchfork, *Park*	8	300	0	0	0
C	91	Plunkett, *Fremont*	17	45	0	11,800	100
C	92	Poison Spider, *Natrona*	20	400	400	954,803	98,641
C	93	Powder River, *Natrona*	8	0	150		
Inc	94	Quealy, *Albany*	5	160	0	628,218	270,967
C	95	Rex Lake, *Albany*	15	200	0	222,014	1,500
C		Rock Creek, *Carbon:*					
C	96	Dakota	21	1,300	0	17,424,242	559,168
C	97	Sundance	4	500	0	541,459	91,918
C		Salt Creek, *Natrona:*					
C	98	1st Wall Creek	30	4,350	0		262,948
C	99	2nd Wall Creek	21	21,450	0		3,052,018
C	100	Lakota	14	2,030	0		563,592
C	101	Sundance	13	660	0		397,619
C	102	Tensleep	8	640	0		220,643
C	103	Shannon, *Natrona*	49	200	0	55,400	Abd.
C	104	Sheep Creek, *Fremont*	4	200	0	10,560	500
C	105	Shoshone, *Park*	10	540	0	10,320	10,320
C	106	Simpson Ridge, *Carbon*	14	160	0	163,825	775
C	107	South Casper Creek, *Natrona*	16	240	0	2,449,120	89,736
C	108	South Sunshine, *Park*	12	300	0	0	0
C	109	Spindletop, *Natrona*	10	80	0	17,493	8,574
C	110	Spring Creek, *Park*	9	2,000	0	33,200	0
C	111	Spring Valley, *Uintah*	38	400	0	101,593	0
C		Teapot, *Natrona:*					
C	112	Wall Creek	16	640	2,000	3,000,000	
C	113	Shale	16	x	0	707,660	6,896
C	114	Torchlight, *Big Horn*	23	600	0	96,000	0
C	115	Warm Springs, *Hot Springs*	21	160	0	319,705	38,795
C	116	Waugh Dome, *Hot Springs*	5	100	0	193,022	5,176
C		Wertz, *Carbon:*					
C	117	Frontier	13	0	100		
Inc	118	Dakota	18	0	500		
Inc	119	Lakota	11	0	500		
Inc	120	Sundance	9	0	200		
C	121	Tensleep	1	250	0	492,811	388,808

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.		Number of Oil and/or Gas Wells					Oil Production Methods at End of 1938			Pressure, Lb. per Sq. Inch[d]		
				During 1938		At End of 1938		Number of Wells				Average at End of	
	To End of 1938	During 1938	Completed to End 1938	Completed	Abandoned	Producing Oil[b]	Producing Gas[c]	Flowing	Pumping	Air Lift, Gas Lift, Water	Initial	1937	1938
62			56	0	0	20	0	0	20				
63			41	0	1	23	0	0	23				
64			17	3	0	10	10	0	1	9			
65			3	2	0	3	0	0	0	3			
66			4	0	0	0	4				1,060	150	150
67	57,186	553	9	0	0	0	5				1,170	200	168
68			2	1	0	2	0		2				
69			32	0	0	32	0						
71	4,938	3,603	13	5	1	10	2	10	0	0	1,900	1,800	1,700
72	0	0	3	0	0	3	0	0	3	0			
73			37	0	0	37	0	0	37	0			
74			1	0	0	1	0	0	1	0			
75													
76			44	1	0	20	0	0	20	0			
77			1	0	0	1	0	0	1	0			
78	5,822	1,240	3	0	0	0	2				1,600	1,260	y
79	1,970	1,970	1	1	0	0	1				2,175	2,175	y
80			2	0	0	2	0		2				
81	40	10	4	0	0	0	4				400	y	y
82			2	0	0	1	0		1				
83			5	0	0	1	0	0	1	0			
84	0	0	2	2	0	0	2				1,200		1,200
85	2,044	259	4	0	0	0	4	0	0	0	720	670	y
86			36	0	0	34	0	0	34	0			
87			470	35	9	370	0	0	370	0			
88			14	1	1	13	0	0	13	0			
89	0	0	2	0	0	0	2				800	800	800
90			1	0	0	1	0						
91			17	2	1	1	0		1				
92	5,600	0	19	0	0	14	0	0	14	0	525		Exh.
93	0	0	7	0	0	0	0	0	0	0	530	525	525
94			19	2	0	17	0	0	17	0			
95			4	0	0	3	0	0	3	0			
96			58	0	2	41		0	41	0			
97			13	2	0	13		5	83	0			
98													
99													
100			1,998										
101													
102													
103			18	0	0	0	0						
104			4	0	0	2	0	0	2	0			
105	0	0	3	1	0	1	0	0	1	0			
106			12	0	0	2	0	0	3	0			
107	11,292	Exh.	17	0	0	17	0	0	17	0			
108			1	0	0	1	0	0	1	0			
109			6	0	0	5	0	0	5	0			
110			3	0	0	1	0	0	1	0			
111			30	0	0	2	0	0	2	0			
112			47	0	0	0	0	0	0	0			
113			15	0	0	2	0	0	2	0			
114			30	0	0	0	0	0	0	0			
115			46	2	0	19	0	0	19	0			
116			2	1	0	0	0	0	0	0			
117			2	0	0		0				850	Exh.	
118			4	0	0		3				1,940	280	440
119	62,245[1]	428	3	0	0	0	3				1,940	280	297
120			1	0	0	0	1				1,520	430	1,200
121			2	1	0	3	0		3				

[1] Frontier, 700 M cu. ft. to end of 1938; exhausted during 1938.

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1938. Gravity A.P.I. of 60° F. Weighted Average	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Ave. in Ft.	Structure[h]	Deepest Zone Tested: Name	Deepest Zone Tested: Depth of Hole, Ft.
62	32	Frontier	CreU	900	175	S	Por	200	Af	Tensleep	4,087
63	32	Dakota-Lakota	Cre	2,100	1,375	S	Por	80	Af		
64	32	Sundance	Jur	2,100	1,875	S	Por	300	Af		
65	35	Tensleep	Pen	4,097	3,900	S	Por	50	Af		
66		Dakota	CreU	2,300	2,170	S	Por	30	A	Tensleep	4,690
67		Sundance	Jur	2,760	2,600	S	Por	110	A		
68	34	Tensleep	Pen	4,760	4,600	S	Por	160	A		
69	22	Embar	Per	1,700	1,450	L	Cav	50	A	Tensleep	2,094
71	63	Sundance	Jur	5,430	5,200	S	Por	140	A	Chugwater	5,910
72	32	Frontier-Muddy	CreU	5,250	5,200	S	Por	60	A	Chugwater	6,689
73	32	Lakota	CreL	1,550	1,500	S	Por	25	A	Minnelusa	3,185
74	32	Minnelusa	Pen	3,180	3,170	S	Por	10	A		
75											
76	37	Dakota-Lakota	Cre	350	170	S	Por	30	A	Madison	3,047
77	35	Minnelusa	Pen	2,830	2,800	H	Fis	10	A		
78		Frontier	CreU	4,340	4,270	S	Por	150	AF	Madison	8,112
79		Dakota	CreU	5,320	5,306	S	Por	60	AF		
80	23	Tensleep	Pen	3,210	3,200	S	Por	10	A	Tensleep	3,308
81		Frontier	CreU	2,400	2,200	S	Por	30	AF	Frontier	2,800
82	16	Tensleep	Pen	3,700	3,475	S	Por	60	A	Tensleep	3,712
83	23	Tensleep	Pen	2,850	2,800	S	Por	40	A	Tensleep	2,830
84		Sundance	Jur	2,353	2,225	S	Por	90	A	Sundance	2,353
85		Dakota	CreU	1,550	1,500	S	Por	45	Af		
86	21	Embar-Tensleep	Per, Pen	3,900	3,500	LS	Cav, Por	150	Af	Madison	4,160
87	41	Newcastle	CreU	2,154	220	S	Por	10	ML	Minnelusa	2,235
88	36	Niobrara	CreU	1,000	800	H	Fis	x	A		
89		Muddy	CreU	3,370	3,350	S	Por	18	A	Sundance	4,630
90	18	Tensleep	Pen	3,950	3,750	S	Por	40	A	Tensleep	3,903
91	42	Mowry	CreU	500	250	H	Fis	x	N	Embar	2,500
92	22	Sundance	Jur	1,425	1,400	S	Por	35	A	Granite	4,119
93		Frontier	CreU	1,350	1,315	S	Por	35	A	Chugwater	3,460
94	35	Muddy-Dakota	CreU	3,320	3,260	S	Por	60	A	Sundance	4,207
95	34	Dakota	CreU	3,900	3,800	S	Por	50	A	Lakota	3,930
96	35	Dakota	CreU	3,300	2,600	S	Por	110	A	Embar	5,627
97	33	Sundance	Jur	3,250	3,150	S	Por	100	A		
98	36	1st Wall Creek	CreU	1,100	1,000	S	Por	110	Af	Granite	5,400
99	36	2nd Wall Creek	CreU	2,575	1,535	S	Por	65	Af		
100	38	Lakota	CreL	2,350	2,300	S	Por	20	Af		
101	35	Sundance	Jur	2,875	2,750	S	Por	70	Af		
102	35	Tensleep	Pen	3,980	3,970	S	Por	190	Af		
103	24	Shannon	CreU	900	800	S	Por	75	MUP	Shannon	y
104	25	Embar	Per	2,100	2,035	L	Cav	75	A	Tensleep	3,905
105	21	Embar	Per	5,000	4,300	L	Cav	24	A	Tensleep	4,775
106	21	Quealy	CreU	675	625	S	Por	40	A	Steele Sh.	6,931
107	15	Tensleep	Pen	2,700	2,600	S	Por	150	A	Tensleep	2,700
108	18	Embar	Per	2,514	2,475	L	Cav	40	A	Embar	2,514
109	22	Sundance	Jur	1,125	1,100	S	Por	25	A	Tensleep	2,705
110	16	Embar-Tensleep-Amsden	Per, Pen	4,255	3,660	LS	Cav, Por	270	A	Amsden	4,255
111	38	Aspen	CreU	900	400	H	Fis	x	MC	Bear River	2,065
112	35	Wall Creek	CreU	2,950	2,900	S	Por	40	Af	Frontier	3,140
113	35	Shale	CreU	1,600	1,200	H	Fis	x	Af		
114	46	Mowry	CreU	600	400	SH	Por	50	A	Madison	4,165
115	21	Embar	Per	800	700	L	Cav	50	A	Tensleep	1,590
116	28	Embar	Per	3,807	3,775	L	Cav	35	A	Tensleep	4,246
117		Frontier	CreU	2,260	2,210	S	Por	50	A	Tensleep	5,883
118		Dakota	CreU	3,550	3,500	S	Por	50	A		
119		Lakota	CreL	3,750	3,700	S	Por	40	A		
120		Sundance	Jur	4,120	4,100	S	Por	20	A		
121	34	Tensleep	Pen	5,886	5,859	S	Por	27	A		

but it will be held as a reserve for the lines of the Northern Utilities Co. extending from Lander, Wyo., to Lewellen, Nebraska.

The Beaver Creek dome is the south dome of the Beaver Creek anticline, a major fold roughly paralleling the Sand Draw line of folding. The north dome is called the Riverton dome. It is structurally 75 ft. lower than the Beaver Creek dome.

The Beaver Creek anticline starts at the Sweetwater escarpment in sec. 8-31N-95W, and trends northwest to near the south line of sec. 10-33N-96W, where it swings abruptly and plunges to the north. It is cut by a transverse fault in sec. 11 and 14-33N-96W. Structural closure in surface beds is a little over 100 feet.

During the years 1936 and 1937, the Stanolind Oil & Gas Company and others conducted scientific surveys in the area, and the location, which is on the surface high, was selected after this work had been completed.

Hamilton Dome Field.—The Hamilton Dome Field in Hot Springs County, Wyoming, was again extended by an operation of Italo Petroleum Corporation, this time about ¼ mile northeast but outside of the proved limits of the field. The field was extended about the same distance northwest in 1937 by the same company.

The new oil well for Hamilton dome is No. 1 Skelton-Government on the SW.SE.NE. of sec. 13-44N-98W. It was completed late in December in Embar lime at 2875 to 2901 ft. and pumped initially 73 bbl. of oil a day. Drilling started in Thermopolis shale just below the Mowry outcrop. The Sundance sand at 1434 to 1450 ft. carried water, which was cased off with 10-in. cemented at 1750 ft. The top of the Chugwater red beds was logged at 1512 ft. and the top of the Embar lime at 2820 ft., with first saturation at 2875 ft. where the 8¼-in. production string was cemented with 200 sacks. The Tensleep sand remains to be tested in this well, but because there is a limited market for black oil at present, deepening operations are not contemplated. The well to the northwest, completed by Italo in 1937, is reported to have obtained its production in Tensleep sand at 3206 to 3246 feet.

Hamilton dome is one of the more important black-oil fields of Wyoming. It produces oil of 19° gravity from the Chugwater red beds and oil of 26.3° gravity from Embar lime. The oil carries a satisfactory gasoline content but its chief value is for blending with oils from other fields that carry a gasoline fraction with a low octane number. The blending process makes a very good refining oil from which a satisfactory octane number can be obtained in the distilled gasoline.

Shoshone Anticline.—The development of the Shoshone anticline field was started in July 1938, by the completion of Paul Stock's No. 1 Bertha M. Rousseau, on the SE.SE.NE. of sec. 20-53N-101W. This is not the discovery well of the field but it is an important extension of the

producing area. The Stock well was completed in Embar lime at a total depth of 4809 ft. and flowed at the rate of 10 bbl. of oil an hour after treating twice with acid, a total of 2000 gallons.

The Shoshone anticline is formed in beds of Frontier age. It is 5 miles long with 1320 ft. of closure and contains 680 acres above the closing contour. This structure has been known for many years and numerous tests were drilled in the early development of Wyoming fields, which were completed in the shallow Muddy sand at about 800 ft. as small pumping wells. From 1924 to 1928 several wells were drilled to deeper horizons, some of which developed good showings of oil in the Greybull sand. The deep test of the structure was completed in 1929 by The Ohio Oil Co. in the NW.NW. of sec. 27-53N-101W. This well was completed for an initial production of 45 bbl. of oil per day from Embar lime at 4752 to 4765 ft., after plugging back from a total depth of 4780 ft., where sulphur water was encountered. The top of the red beds was logged at 3560 feet.

Mahoney Dome.—The Sinclair Wyoming Oil Co. began the development of Mahoney dome for oil with the completion, in October 1938, of its No. 3 Mahoney, C.SE.NW. of sec. 34-26N-88W, in Tensleep sand at 4295 to 4486 ft. The well flowed 635 bbl. of oil from the total depth through the casing and was then shut in for tankage. Through the tubing the well flowed 172 bbl. of oil per day.

The discovery oil well of the Tensleep sand was drilled jointly by the Producers & Refiners Corporation and the Midwest Refining Co., on the same forty in which the No. 3 Mahoney well is located. It was completed in 1930 and produced about 75 bbl. of oil per day from Tensleep sand at 4600 to 4682 ft. after plugging back from a total depth of 4760 ft. A shot of 140 quarts of nitroglycerin did not increase the production. The oil is of a mixed base and has a gravity of about 32°.

The Mahoney dome is on the northern rim of the Lost Soldier Basin. It is an east-west structure, 2½ miles long and 2 miles wide above the lowest closing contour. The structure is formed in Niobrara shale and is badly covered by wind-blown sands.

The discovery well of the field was completed in September 1919, by the old Kasoming Oil Co., at a location in the SW.SW.NE. of sec. 34-26N-88W. It developed a flow of gas estimated at 30,000,000 cu. ft. per day from the first producing horizon of the Dakota series at 2160 feet.

Muskrat Field.—Sinclair Wyoming Oil Co. extended the gas-producing area of the Muskrat field in Fremont County, by the completion in June 1938 of its No. 2-B Muskrat, NW.NW.NE. of sec. 4-33N-92W, for an initial production of 40,000,000 cu. ft. of gas in Lakota (Lower Cretaceous) sand at 5306 to 5320 feet.

This well is of particular interest because it is on a dome on the southwest flank of the main axis of the Muskrat anticline. The folding

along the main axis suggests domal structure at this point but detailing of the dome by surface methods is impossible because the area is covered by an overlap of flat-lying Wind River (Tertiary) beds. A seismograph survey made in 1936 by Sinclair Wyoming Oil Co. confirmed the location of the structural high that led to the drilling of No. 2-B Muskrat.

The Muskrat gas field is served by the Sand Draw-Casper lines of the Northern Utilities Co. It is one of the more important Wyoming gas fields and its reserves are impressive.

Pipe Lines

The major pipe-line project in the entire Rocky Mountain region for 1938 was the construction of a trunk line from the Lance Creek field, in eastern Wyoming, to Denver, a distance of 232 miles. The line was built by the Rocky Mountain Pipe Line Co., which was incorporated in Delaware for 5000 shares of $100 par value. Principal capital requirements were met by the issuance of serial notes, of which 55 per cent was acquired by Continental Oil Co.; 25 per cent by C. U. Bay, president of Bay Petroleum Corporation; and 20 per cent by Fred Goodstein, of Minnelusa Oil Corporation. The Bay refineries at Cheyenne and Denver, and the Continental refinery, on the Brighton road near Denver, will receive crude from Lance Creek through the new line under long-time contracts.

Construction of the line was commenced on Aug. 22, 1938, and it was placed in operation on Nov. 1, 1938. The line consists of 136 miles of 25.29-lb. 8-in. pipe from Lance Creek to Cheyenne, and 96 miles of 17.02-lb. 6-in. pipe from Cheyenne to Denver, and has a capacity of 10,000 bbl. of oil a day. In addition to a complete telephone system over the route of the line, pump stations have been built in the field at Guernsey and Cheyenne, Wyoming.

Late in 1938, Continental Oil Co. completed 66.4 miles of oil-pipe line from the Lance Creek field to its refinery at Glenrock, Wyo. This line consists of 14.9 miles of 6-in. and 51.5 miles of 4-in. pipe.

The Mountain Fuel Supply Co. completed a loop system to its main trunk gas line between the Bigelow Hills, east of Evanston, Wyo., and Coalville, Utah, a distance of 53 miles. The double line is of 18-in. pipe. This pipe line is the outlet for gas from the Green River Basin fields in southern Wyoming, northwestern Colorado and northeastern Utah, which supplies the larger towns in southwestern Utah, and in the Salt Lake area.

The Northern Utilities Co. completed the looping of its Muskrat-Casper line in 1938. The pipe used for the loop system was from the old Rawlins-Casper line taken up in 1937.

The Ohio Oil Co. has strung 6-in. pipe from the newly discovered Oil Springs gas field to a junction with its Allen Lake-Laramie line, a

distance of 10 miles. The line will be laid and put in operation early in the spring.

Acknowledgment

The information used in this paper has been adapted to the requirements of the A.I.M.E. by abridgment of articles from the annual publication of Petroleum Information, Inc., titled Résumé of Rocky Mountain Oil and Gas Operations for 1938.

G. H. Gaul assisted in the compilation of the table of statistics.

Development of Petroleum Activities in the Argentine Republic during 1938

By Mario L. Villa*

During 1938, oil activities in the Argentine Republic showed a favorable balance due to the increase in crude-oil production, the incorporation of new producing areas and the discovery of deeper productive horizons. Drilling was as follows:

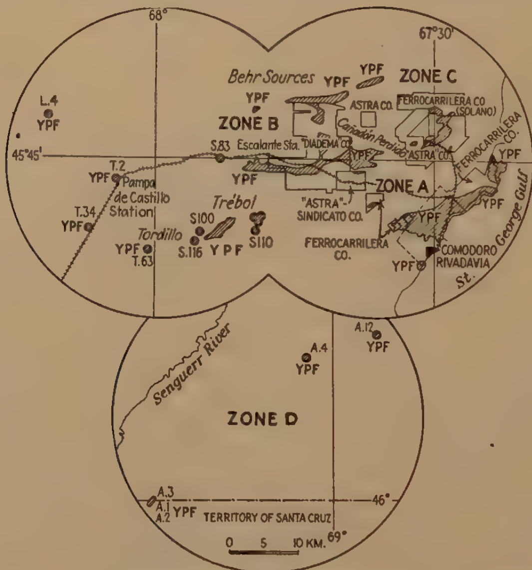

Fig. 1.—Oil-bearing zones, Territory of Chubut.

Province or Territory	Wells Completed	
	Productive	Dry
Chubut	260	24
Neuquén	15	4
Salta	12	6
Mendoza	8	5

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The total production of crude oil amounted to 17,076,243 bbl., an increase of 4.41 per cent above the year 1937. The increase of 721,537 bbl. is exclusively the contribution of the Y.P.F. (Argentine Government oil fields). While the Y.P.F. production increased by 1,061,123 bbl.

FIG. 2.—OIL-BEARING ZONES, TERRITORY OF NEUQUÉN.
FIG. 3.—OIL-BEARING ZONES, PROVINCE OF SALTA.
FIG. 4.—OIL-BEARING ZONES, PROVINCE OF JUJUY.
FIG. 5.—OIL-BEARING ZONES, PROVINCE OF MENDOZA.

FIG. 6.—TERRITORY OF SANTA CRUZ.

(13.36 per cent above the 1937 production), the production from privately owned wells decreased by 339,586 bbl. (4.03 per cent).

The 14,110,608 bbl. produced at Comodoro Rivadavia (Chubut) represent 82.63 per cent of the country's total production.

Salta produced 1,777,624 bbl., a decrease of 71,227 bbl., or 3.85 per cent, from last year, notwithstanding that Y.P.F. increased its produc-

tion with the development of the new horizon in southern Tranquitas (Tartagal zone).

Plaza Huincul's production was about the same as last year. The increase registered in zone 2 as the result of the extension of its productive area affected only the last three months of the year and compensated the decrease in other zones.

FIG. 7.—LOCATIONS OF OIL-BEARING ZONES IN THE ARGENTINE REPUBLIC.

Mendoza's production, 201,142 bbl., represents an increase of 78.26 per cent over last year's production. The increase of 61,152 bbl. shown by the Tupungato zone is due to one well, the T.19, which began to produce in November 1938.

Bottom-hole pressure has been determined systematically in the newly incorporated productive areas. In the new pool of El Trébol

(zone B Chubut) an average yearly pressure of 750 lb. per sq. in. has been determined. In Tranquitas Sud (zone Tartagal, Salta) an average pressure of 540 lb. per sq. in. was registered in the upper horizon, and of 870 lb. per sq. in. in the deeper one.

Special mention should be made of the conservation program applied by Y.P.F. from the beginning for maintaining bottom pressure in Tranquitas Sud, which up to the end of 1938 produced 1,983,750 bbl. of crude oil—also 102,758,000 cu. ft. of gas, which was returned to the formation—representing 98.50 per cent of the total obtained with the crude oil produced by the flowing wells. A decrease of only 2.30 per cent of the bottom pressure was registered.

Directional drilling was used by the Y.P.F. in Comodoro Rivadavia, on the Atlantic shore, to reach oil horizons at points under the sea or at other inaccessible places.

Table 2 gives a summary of exploration wells that are outstanding because of their contribution to oil-field developments or information obtained from them. Wells S.121, E.12, E.50 and S.116 are 25 km. or more to the west of the town of Comodoro Rivadavia, and wells H.7 and H.8 at approximately 30 km. northeast of the same town. They

TABLE 1.—*Oil and Gas Production in the Argentine Republic*

Line Number	Field, *Territory or Province*	Age, Years to End of 1938	Area Proved, Acres: Oil	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1938	Total Oil Production, Bbl.: During 1937	Total Oil Production, Bbl.: During 1938	Total Oil Production, Bbl.: Daily Average during Nov. 1938	Total Gas Production, Millions Cu. Ft.: To End of 1938
	Comodoro Rivadavia, *Chubut Territory*								
1	Zone A	31	14,510	14,510	99,475,979	5,985,268	4,973,931	13,416	156,141
2	Zone B	14	17,050	17,050	42,130,621	6,477,932	8,220,627	22,147	29,095
3	Zone C	21	3,707	3,707	16,179,244	942,795	916,050	3,095	9,887
4	Zone D	4			24,549	188			
	Plaza Huincul, *Neuquén Territory*								
5	Zone 1	20	138	138	1,601,226	76,794	56,446	126	1,705
6	Zone 2	12	1,359	1,359	3,178,645	378,815	497,948	1,862	6,543
7	Zone 3	14	504	504	9,232,223	519,661	425,009	1,088	9,223
8	Zone 4	4	57	57	43,243	9,995	7,384	23	1,624
	Province of Salta								
9	Zone Tartagal	12	618	618	3,918,897	367,084	465,083	1,585	5,893
10	Zone San Pedro	10	450	450	8,727,998	1,368,006	1,229,299	3,038	9,417
11	Zone Aqua Blanca	12	136	136	867,699	113,761	83,242	182	21
	Province of Jujuy								
12	Zone Yuto	2	32	32	3,397	1,572	82		
	Province of Mendoza								
13	Zone Cacheuta	7	667	667	263,915	71,586	107,307	377	
14	Zone Tupungato	5	247	247	128,995	14,970	76,122	962	23.8
15	Zone Sosneado	13	124	124	254,795	26,279	17,713	42	
16	Total		39,599	39,599	186,031,426	16,354,706	17,076,243	47,943	229,572.8

are within zone B (Chubut) and were drilled by Y.P.F. Well S.121 has proved that the horizon being worked at El Trébol maintains its satisfactory productivity several kilometers to the east. Well E.12, on the same structure, which was considered a deep test, has proved the existence of a deeper oil horizon. Well E.50, west of El Trébol, revealed the existence of several paying oil sands below El Trébol horizon. Well S.116 has shown the existence of deeper horizons of satisfactory production in the Chubutiano. Wells H.7 and H.8 discovered a new, very promising oil area. Two different horizons, of good production, separated some 200 m. have been found.

Y.P.F. started the exploration of the Gran Bajo Oriental with well O.1. Although a dry hole, it provided valuable information for future exploration work. Y.P.F.'s well SC.2, near Rio Gallegos, has been drilled to examine the series of existing formations down to the basement. It was abandoned in the porphyritic rocks considered as belonging to Triassic age.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.			Number of Oil and/or Gas Wells							Depth, Average in Feet		Oil Production Methods at End of 1938					Pressure, Lb. per Sq. In.[d]		
	During 1937	During 1938	Maximum Daily during 1938	Completed to End of 1938	During 1938		At End of 1938				Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells				Injection into Reservoir*	Initial	Average at End of	
					Completed	Abandoned	Temporarily Shut Down	Producing Oil[b]	Producing Gas[c]	Total Producing			Flowing	Pumping	Gas Lift	Miscellaneous			1937	1938
1	8,827	7,239	23.6	2,387	57	4	238	1,687	21	1,708	2,493	2,198	26	1,651		10	21			
2	4,131	5,438	17.3	671	152		81	432	25	457	3,772	3,674	6	411	14	1	25	630	630	512[2]
3	600	989	3.2	710	51	26	189	323	21	344	2,132	1,963		323			21			
4				5							2,624	2,296								
5	226	226	0.7	84			12[1]	40	2	42	1,988	1,876		1	39		2			
6	611	1,070	4.6	150	12	1	20	98	7	105	2,503	2,368	14	83		1	7	724[3]		
7	650	611	1.8	213	1	4	25	134	9	143	2,588	2,398		133		1	9			
8	847			10	2	3		2		2	3,365	3,362		2						
9	674	766	2.5	162	8	4	24	109		109	1,768	1,469	17	37	55			640	640	625[4]
10	1,201	1,261	3.5	45	2		14	31		31	2,850	2,795	24	6		1		600	540	540
11	21			10	2		3	6		6	4,920	4,592	1	5						
12				5				2		2	5,751	5,192		2						
13				38	7		7[1]	26		26	2,001	1,998	1	22		3				
14		23.8	0.7	12	1		4[1]	10		10	5,891	5,881	10					1,566*x*	*x*	*x*
15				14			2	12		12	551	544		12						
16	17,788	17,623.8	57.9	4,516	295	42	619	2,912	85	2,997	3,013	2,840	99	2,688	108	17	85			

[b] Footnotes to column heads and explanation of symbols are given on page 240.
[1] Including wells to be abandoned.
[2] Corresponding to the pool of El Trébol.
[3] Corresponding to the new area.
[4] Corresponding to the upper horizon of southern Tranquitas.
* Numbers indicate number of injection wells.

Y.P.F. well No. 294 apparently has found a new oil area in a partial structure and at a greater depth than Plaza Huincul's principal one. Standard Oil Company wells H.53 and H.56 and Y.P.F. well NI.2 have proved a new extension of good production, in the lower part of the Mina Chita structure, west of Plaza Huincul. Y.P.F. well NB.8 found only a small amount of crude and was abandoned in the Liassic as unproductive. Well NE.10, drilled by Y.P.F. 1000 ft. below the normal productive oil horizon, which showed only a small amount of oil, discovered in the subjacent formations of the Liassic different gas horizons with pressures of 300 to 500 lb. Y.P.F. well T.19, a deep test of the Tupungato anticline, was the most successful of the year, flowing 2520 bbl. of crude oil per day from the Rético.

Well SC.1, on the San Carlos anticline (Mendoza), reached a depth of 6580 ft., and is of geological interest because it shows that the Tertiary strata lay directly above strongly folded formations of the basement.

The Y.P.F. well RP.3, drilled in Rio Pescado (Salta), has been productive, confirming that a high-pressure field is being developed. Among

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1938				Character of Gas, Approx. Average during 1938		Producing Formation						Number of Dry and/or Near-dry Holes to End of 1938	Deepest Zone Tested to End 1938	
	Gravity A.P.I. at 60° F														
	Maximum	Minimum	Weighted Average	Base[e]	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[e]	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]		Name	Depth of Hole, Ft.
1	20.6	24.0	22.3	PA	854	3.74	Glauconitico y Chubutiano	Cre	Sand	Por	29.5	AF	151	Chubutiano	7,592
2	20.5	34.6	27.6	PA	854	3.59	Glauconitico y Chubutiano	Cre	Sand	Por	32.8	AF	129	Chubutiano	6,235
3	19.0	22.3	20.7	PA	853		Glauconitico y Chubutiano	Cre	Sand	Por	13.1	AF	101	Chubutiano	
4	23.1	23.1	23.1	PA	853		Glauconitico y Chubutiano	Cre	Sand	Por	26.2	AF	3		
5	29.8	33.0	31.4	PA	904	10.08	Dogger	Jur	S	Por	39.3	Mu	36		
6	30.4	31.1	30.8	PA	904	10.31	Dogger	Jur	S	Por	32.8	Mu	13	Liassic	4,856
7	33.0	35.0	34.0	PA	904	11.06	Dogger	Jur	S	Por	55.7	Mu	48	Liassic	4,202
8	37.0	43.2	40.1	PA	904		Dogger	Jur	S	Por	19.7	Mu	8	Liassic	5,038
9	43.8	45.4	44.6	P	915	8.22	[5]	Ter	S	Por	32.8	A	45	Gondwana	3,852
10	44.7	46.0	45.4	P	915	8.22	[6]	Perm	S	Por	29.5	A	14	Devonian	3,223
11	22.8	23.1	23.0	P	915	2.99	[7]	Perm	S	Por	19.7		6	Gondwana	4,372
12	30.8	33.4	32.1	PA		2.15	Horizonte Calcáreo	Ter	LS		32.8			Calcáreo	6,416
13	17.1	31.1	24.1	PA	859	5.98	Estratos de Potrerillos	Lias	S		13*y*	AF	8	Liassic	
14	31.1	33.0	32.1	P	859	5.98	Tupungato Ss	Lias	S		16*y*	AF	6	Liassic	5,891
15	11.0	12.9	12.0	A	859		Titoniano	Juras	S		13*y*	MIF	6	*x*	
16													574		

[5] Calc´reo, Areniscas Inferiores, Gondwana.
[6] Calcáreo, Areniscas Inferiores, Gondwana, Devonian.
[7] Areniscas Inferiores y Gondwana.

TABLE 2.—*Summary of Drilling Operations in the Argentine Republic*

IMPORTANT WILDCATS DRILLED IN 1938

	Province or Territory	Location	Well	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Initial Production of Oil per Day, Bbl.	Remarks
1	Chubut	Comodoro Rivadavia	S.121	4,661	Pliocene	Upper Cretaceous	Y.P.F.	503	
2	Chubut	Comodoro Rivadavia	E.50	5,799	Pliocene	Upper Cretaceous	Y.P.F.	76	
3	Chubut	Comodoro Rivadavia	S.116	5,671	Pliocene	Upper Cretaceous	Y.P.F.	252	
4	Chubut	Comodoro Rivadavia	E.12	5,970	Pliocene	Upper Cretaceous	Y.P.F.	76	
5	Chubut	Comodoro Rivadavia	H.7	3,782	Pliocene	Upper Cretaceous	Y.P.F.	315	
6	Chubut	Comodoro Rivadavia	H.8	4,505	Pliocene	Upper Cretaceous	Y.P.F.	723	
7	Santa Cruz	Gran B. Oriental	O.1	4,428	Lower Tertiary	Upper Cretaceous	Y.P.F.		Dry hole
8	Santa Cruz	R'o Gallegos	SC.2	4,284	Miocene	Triassic	Y.P.F.		Dry hole
9	Neuquén	Plaza Huincul	294	4,856	Upper Cretaceous	Jurassic	Y.P.F.	283	
10	Neuquén	Plaza Huincul	H.53	2,631	Upper Cretaceous	Jurassic	Standard Oil Co.	220	
11	Neuquén	Plaza Huincul	H.56	2,509	Upper Cretaceous	Jurassic	Standard Oil Co.	224	
12	Neuquén	Plaza Huincul	NI.2	2,529	Upper Cretaceous	Jurassic	Y.P.F.	535	
13	Neuquén	Plaza Huincul	NB.8	4,202	Upper Cretaceous	Liassic	Y.P.F.		Dry hole
14	Neuquén	Plaza Huincul	NE.10	5,038	Upper Cretaceous	Liassic	Y.P.F.		Dry hole
15	Mendoza	Tupungato	T.19	5,891	Upper Tertiary	Rético	Y.P.F.	2,520	
16	Mendoza	San Carlos	SC.1	6,580	Upper Tertiary	Paganzo	Y.P.F.		Dry hole
17	Salta	R'o Pescado	RP.3	4,372	Upper Tertiary	Tertiary	Y.P.F.	214	
18	Salta	Ramos	R.9	3,920	Tertiary	Devonian	Standard Oil Co.	31	
19	Salta	Lomitas	L.81	2,335	Tertiary	Gondwana	Standard Oil Co.	365	
20	Jujuy	Moralitos	1	1,699	Tertiary	Cretaceous	Ultramar		In observation

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1938	29	20
Number of oil wells completed during 1938	265	21
Number of gas wells completed during 1938	8	1
Number of dry holes completed during 1938	21	18

other wells completed in Salta, mention should be made of the Standard Oil Company's Ramos 9, which produced 31 bbl. of crude oil from the Devonian, and Lomitas 81, deepened by the same company in the northern zone—Tranquitas—which found a very deep oil horizon of great productivity.

With Ultramar's Moralito 1, exploration activities west of San Pedro (Jujuy) have started again. This well is still under observation.

Y.P.F. has continued geophysical investigations, having one party working with reflection seismographs in the Chubut Territory during all the year, one in Neuquén for eight months, one in the Province of Salta

for four months and one in the Province of Santa Fé during December. Gravimetric and magnetometric parties worked in the Provinces of Mendoza, Córdoba and Salta.

TABLE 3.—*Zones into Which Productive Areas of the Argentine Republic Have Been Subdivided*

Territory or Province	Zones	Location	Companies
Chubut	A	Atlantic coast (Comodoro Rivadavia)	Y.P.F., Ferrocarrilera and Sindicato (Astra).
	B	Km. 27, Escalante, Canadón Perdido, Manantiales Behr, El Trébol	Y.P.F., Diadema Argentina and Sindicato (Astra).
	C	Km. 20, Astra	Astra and Solano (Ferrocarrilera).
	D	Pampa de María Santísima (Colonia Sarmiento)	Y.P.F.
Neuquén	1	Centro Octógono de Reserva (Plaza Huincul)	Y.P.F.
	2	Oeste Octógono de Reserva (Plaza Huincul)	Y.P.F. and La República (Standard Oil Co.).
	3	Laguna Colorada (Plaza Huincul)	Y.P.F., Standard Oil Co. and Astra.
	4	Bajo de Los Baguales (Plaza Huincul)	Y.P.F.
Salta and Jujuy	Tartagal	Tranquitas, Vespucio and Lomitas (Departamento de Orán)	Y.P.F. and Standard Oil Co.
	San Pedro	Sierra del Rio Seco (Depto. de Orán)	Standard Oil Co.
	Agua Blanca	Agua Blanca and Rio Pescado	Y.P.F. and Standard Oil Co.
	Yuto	Laguna de la Brea (Jujuy)	Y.P.F.
Mendoza	Cacheuta	Luján de Cuyo	Y.P.F.
	Tupungato	Villa Tupungato	Y.P.F.
	Rio Atuel	El Sosneado (San Rafael)	Compañía Rio Atuel

Petroleum and Gas in Australia

By Arthur Wade*

During the year 1938, there was some drilling in Queensland, New South Wales and Victoria, as follows:

Queensland.—At Hutton Creek, lat. (approx.) 25° 45′ S.; long. (approx.) 149°, drilling was done by Drillers Limited (subsidiary Oil Search) to a depth of 4688 ft., to the Lower Permian(?). There were small gas showings. The hole was abandoned.

At Mt. Bassett, lat. (approx.) 26° 20′ S.; long. (approx.) 149°, Roma Blocks Oil Co. No Liability drilled to a depth of 4033 ft. The hole bottomed in granite. There were small showings of oil and gas above bedrock in what may be Permian but is not yet determined. The company intends to run a formation tester.

New South Wales.—At Kulnura, lat. (approx.) 33° S.; long (approx.) 151°, the Kamilaroi Oil Company Ltd. (subsidiary of Oil Search Ltd.) drilled to a depth of 6293 ft. The Permian, probably Upper Marine Series, was reached. Drilling is to continue.

Victoria.—At Romawi, lat. (approx.) 37° 50′ S., long. (approx.) 147° 45′, a dry hole 3246 ft. deep bottomed in the Jurassic and was abandoned. It was drilled by the Governments of the Commonwealth and the State of Victoria.

At Lakes Entrance, lat. (approx.) 37° 50′ S.; long. (approx.) 148°, a small showing of oil (a few pints a day) was obtained from a well drilled 1275 ft., to the Upper Oligocene-Glauconite series, by the Austral Oil Drilling Syndicate, No Liability.

Future Drilling

Preparations are being made by companies for further test drilling in 1939, and the Governments of the Commonwealth and the State of Victoria are continuing test holes for information only in the Gippsland district of Victoria.

In Papua and New Guinea, no test drilling was done in 1938, but several companies are carrying on geological investigation and it is expected that some test holes will be drilled during 1939.

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* Chairman of the Commonwealth Oil Advisory Committee, Canberra, A. C. T., Australia.

Petroleum in Bahrein Island, 1938*

Production of crude oil in Bahrein Island during 1938 reached the new high of 8,297,998 bbl., an increase of 535,734 bbl. over the 1937 production of 7,762,264 bbl. The monthly average during 1938 was 691,500 bbl. and the daily average 22,734 barrels.

To the close of December 1938, a total of 52 producing wells have been drilled. During the year 13 producing wells were completed and 11 wells were drilling or partly completed as of Dec. 31, 1938. The total footage drilled as of Dec. 31, 1938, amounted to 165,339 ft., of which 60,739 ft. was drilled during 1938.

The production from the main pay comes from a depth of approximately 2200 ft. and the gravity of the oil is 33° A.P.I.

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* Information received through the Courtesy of the Bahrein Petroleum Company Ltd. Manuscript received at the office of the Institute March 1, 1939.

Oil Developments in Canada in 1938

By G. S. Hume

(New York Meeting, February, 1939)

Turner Valley, on the eastern edge of the foothills of Alberta, 35 miles southwest of Calgary, continues to be the major oil field in Canada. This field began production of gas and naphtha from the Mississipian (Madison) limestone in 1924, and until 1936 all wells were drilled for these products. At the end of 1938 there were 104 gas wells.

In 1936 proof was found of a crude oil zone in the same horizon but lower on the west flank of the structure, which is a large fold cut off on the east side by an overthrust fault of great displacement. Since 1936 drilling has been done for the development of crude oil and at the end of 1938 there were 64 crude oil wells. On test through a 1-in. choke these flowed at the rate of 50,000 to 60,000 bbl. a day, but on production would not be expected to make this volume. The output has been prorated

Table 1.—*Production of Petroleum and Natural Gas in Canada*

Province	Petroleum, Barrels of 35 Imperial Gal. (42 U. S. Gal.)			Natural Gas, Thousands of Cubic Feet	
	1936	1937	1938[a]	1937	1938[a]
Alberta	1,310,000	2,796,908	6,742,039	17,058,439	21,792,779
Saskatchewan				92,528	87,422
Ontario	165,495	164,197	172,059	10,190,334	10,696,833
Manitoba				600	600
New Brunswick	17,112	22,549	19,277	576,629	581,832
Northwest Territories	5,399	11,371	22,854		
Total	1,498,006	2,995,025	6,956,229	27,918,530	33,159,466

[a] Bureau of Statistics, Ottawa.

according to the capacity of the Prairie market. During the harvest season, when the demand for oil and oil products was at its maximum, the allowable production of Turner Valley was 28,363 bbl. per day. With the arrival of winter, this was cut to 11,500 bbl. per day but later was raised to 12,500 bbl. Production in 1937 from Turner Valley was 2,767,221 bbl., which was more than double that of the previous year. Production in 1938 was 6,691,075 bbl., which is considerably more than double that of 1937.

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* Bureau of Geology and Topography, Department of Mines and Resources, Ottawa, Ontario.

Production of crude oil in Canada and the production in Alberta, where the larger part of the oil is produced, is shown in Tables 1 and 2.

TABLE 2.—*Production of Petroleum in Alberta*

Field	1936	1937	1938[a]	Field	1936	1937	1938[a]
Turner Valley	1,278,000	2,767,221	6,691,075	Skiff	300		
Red Coulee	17,000	13,790	14,458	Taber		600	15,098
Wainwright-Ribstone	14,700	14,697	18,344	Moose Dome		600	3,064
				Total	1,310,000	2,796,908	6,742,039

[a] Bureau of Statistics, Ottawa.

In Turner Valley 36 crude oil wells and one dry hole were drilled during 1938. The deepest well on the west flank reached a depth of 10,209 ft., finding oil in the upper zone of the Madison limestone but salt water in the lower zone, thus determining the western edge of the field. The two porous zones are within the upper 450 ft. of limestone but separated by a hard band. Turner Valley now has two productive areas. The larger of these, in the south end of the field, has a proven length of 5 miles and a proven width of about 2 miles. Various estimates of the recoverable oil content have been made, one of which, on evidence taken before the Tariff Commission, placed the amount at 17,000 to 23,300 bbl. per acre. The other area, 10 miles north of the proven south area, is not so well defined but has several producing wells over a length of more than 2½ miles. The area between the north and south proven areas is all structurally favorable for oil, although at one place a dry hole has been drilled and hence at least a small part of it will be unproductive. From the most northwesterly well in the north proven area, the structure extends several miles farther to the northwest and the amount of productive territory on it will be determined by the subsurface trace of the major thrust fault, which cuts off Turner Valley on the east side, and by the depth of the oil-water line.

Foothills.—In the foothills outside of Turner Valley, there is a small amount of production from the Devonian limestone of Moose Mountain, 35 miles west of Calgary. This area is a limestone outlier in which drilling begins 2000 ft. below the productive limestone horizon of Turner Valley. One well, drilled to a depth of 1680 ft., began near the top of the Devonian and obtained a small volume of oil, which, however, is said to be coming from a fracture rather than a porous zone. The well will be deepened. The structure is a large anticlinal fold and could become an important field if porous reservoir rocks occur at greater depths. Another foothills test of the Devonian limestone is being drilled on Clearwater River, 80 miles northwest of Calgary. Above a depth of 1300 ft., 70 ft. of porous limestone saturated with oil and gas has been encountered. The well was drilled with a diamond drill and the hole has been reamed out

and 3-in. casing inserted. No test has yet been made. This structure is also an anticlinal fold several miles long by 1 to 2 miles wide. Wells on the Birch Ridge uplift northwest of Turner Valley, on the so-called Watson structure, 55 miles south of Turner Valley and on the Bearberry anticline 60 miles northwest of Calgary, have encountered complicated structural conditions without finding production. One well is still drilling on the Watson structure. In the Brazeau area of the foothills, north of the Clearwater area, an incompleted test has been drilled to a depth of 4500 ft., starting in Upper Cretaceous shales. Another test on Ram River south of Brazeau and north of Clearwater is drilling in a limestone outlier in the expectation of testing the Devonian. Still another test of a limestone outlier, which in reality is part of the Livingstone Range, is being made on Savannah Creek about 30 miles south and west of the south end of Turner Valley. No results are yet available.

On the Plains.—On the plains only a few wells in rather widely scattered areas were drilling in 1938. A test that was started in the Peace River district of Alberta in the same general area, as a gas well with an initial flow of 10,000 M cu. ft. per day, was completed in 1923. South of the Ribstone area of eastern central Alberta, where there are two wells each yielding heavy oil at the rate of about 20 bbl. per day, a third well reached a saturated oil sand at 2034 ft. This well was shut down for the winter. East of this area, at Vera, 28 miles east of the Saskatchewan-Alberta boundary, oil with a gravity of 10.9° A.P.I. was found. The volume is not known. Further drilling in Saskatchewan is anticipated in 1939, because of the need of more gas to supply the city of Saskatoon, for which a franchise has been granted. At present the only commercial gas supply in Saskatchewan is obtained from the Lloydminster field, where a number of wells have been completed. Some of these contain gas in large volume and at least two have given evidence of the presence of oil. A number of others, however, have failed to find commercial production of either gas or oil, and the original gas well, completed in 1934, was showing water in 1938. For a number of years this well was the sole supply of gas for the town of Lloydminster but with the drilling of other wells a supply beyond the needs of this town alone is now available. A new well is being drilled in the same general vicinity on the Alberta side of the provincial boundary.

Ontario.—In Ontario the most interesting development during 1938 took place in the vicinity of Watford, Lambton County, east of Sarnia. A small production was obtained in 15 wells from Devonian limestone at a depth of 365 to 480 ft. The largest well had an initial production of about 100 bbl. a day. Although some dry holes have been drilled, the field is not yet completely outlined. As presently developed it is over 2 miles long by 1 mile or more wide. No important new gas fields were discovered in Ontario in 1938 but the Brownsville field near Tillsonburg in Norfolk County is still being developed.

Petroleum Developments in Colombia during 1938

By O. C. Wheeler,* Member A.I.M.E.

(New York Meeting, February, 1939)

During 1938, Colombia witnessed greater activity in oil prospecting and development than in any previous year in its history; more wells were drilled, more potential production established, more geological and geophysical work was accomplished, and more leases and concessions were acquired. Many companies, including the Texas, Socony Vacuum, Richmond (subsidiary of the Standard Oil of California), the Shell, and Tropical, contributed to this activity. Probably the most noteworthy development was in connection with the Barco Concession, which forms part of the Maracaibo Basin in eastern Colombia, adjacent to the Venezuelan frontier. There a great deal of preparatory work was accomplished in addition to camp and other construction, 20 producing wells were drilled and work was begun on the construction of a 12-in. pipe line to transport the oil to the port of Covenas, a distance of 260 miles. It is reported that 58,000 bbl. daily initial production was established during the year and is awaiting an outlet through this pipe line.

Leasing and exploratory operations in Colombia continued active throughout the year; applications were made for concessions covering more than 1,100,000 acres of national lands and, in addition, leases were taken up on large areas of privately owned lands. Under Colombian law

Table 1.—*Oil and Gas Production in Colombia*

Line Number	Field	Age, Years to End of 1938	Total Oil Production, Bbl.			
			To End of 1938	During 1937	During 1938	Daily Average during Nov. 1938
1	Infantas, *Santander*	20	118,208,539	6,481,173	5,472,791	14,557
2	La Cira, *Santander*	12	109,494,542	13,816,673	16,108,797	46,957
3	Las Monas, *Santander*	11				
4	Petrolea, *Santander del Norte*	6	180,879	28,878	60,461	194[1]
5	Rio de Oro, *Santander del Norte*	18	21,632	2,963	18,669	45[1]

[1] December, 1938.

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* Chief Geologist, International Petroleum Co. Ltd., Toronto, Ontario.

subsoil rights are reserved to the nation on all lands granted after Oct. 28, 1873, and all private titles granted prior to that date carry both surface and subsurface rights. As a large part of Colombia was settled in Colonial days, much of the land was acquired before 1873 and, therefore, carries mineral rights. Leasing activity was not confined, as in previous years, to the Magdalena Valley and coastal area, but extended into the more inaccessible llanos of eastern Colombia.

Most of the geophysical work was carried on in the Magdalena Valley, but some work was done in eastern Colombia as well. Various types of geophysical instruments were used, including principally the seismograph and gravity meter. Extensive areas of Colombia have now been mapped photographically both in the Magdalena Valley and in eastern Colombia.

Operating Companies

Colombian Petroleum Co.—By the completion of 22 wells on the Barco Concession during 1938, the productive areas of the Petrolea and Rio de

Table 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells			Depth, Average in Feet		Oil-production Methods at End of 1938			
	Completed to End of 1938	During 1938		Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells			Injection into Reservoir
		Completed	Abandoned			Flowing	Pumping	Miscellaneous	
1	470	1	2	1,000–2,600	400–2,200	46	597		31*
2	500	110	0	600–4,294	400–3,950				
3									
4	29	17	0	440–3,007	396–1,381	29			
5	6	3	0	1,170–1,615	1,130–1,585	5			

Line Number	Character of Oil, Approx. Average during 1938					Character of Gas, Approx. Average during 1938	Producing Rock						Number of Dry and/or Near-dry Holes to End of 1938	Deepest Zone Tested to End of 1938	
	Gravity A.P.I. at 60° F.			Sulphur, Per Cent	Base†	B.t.u. per Cu. Ft.	Name	Age[e]	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]		Name	Depth of Hole, Ft.
	Maximum	Minimum	Weighted Average												
1	35	23	25.0	0.90	A	1,050	A, B, C zones	Olig, Eoc	S	15–22	50–200	AF	17	Cre	4,048
2	27	20		0.90	A	1,050	A, B, C zones	Olig, Eoc	S	15–25	50–175	AF	1	Cre	7,983
3					A			Eoc	S			AF	4	Cre	
4	47.5	37.7	43.8				Cogollo	CreL	L & Slt			A	7	CreL	3,007
5	39.5	32.5	38.6				Catatumbo	Eoc	S			A	3	CreL	6,717

Footnotes to column heads and explanation of symbols are given on page 240.
* Number of injection wells.
† A, asphalt.

Oro structures were extended, and several additional areas were being tested. Seventeen producing wells were completed in the Petrolea field; one dry hole, and three producers with a total initial daily potential of

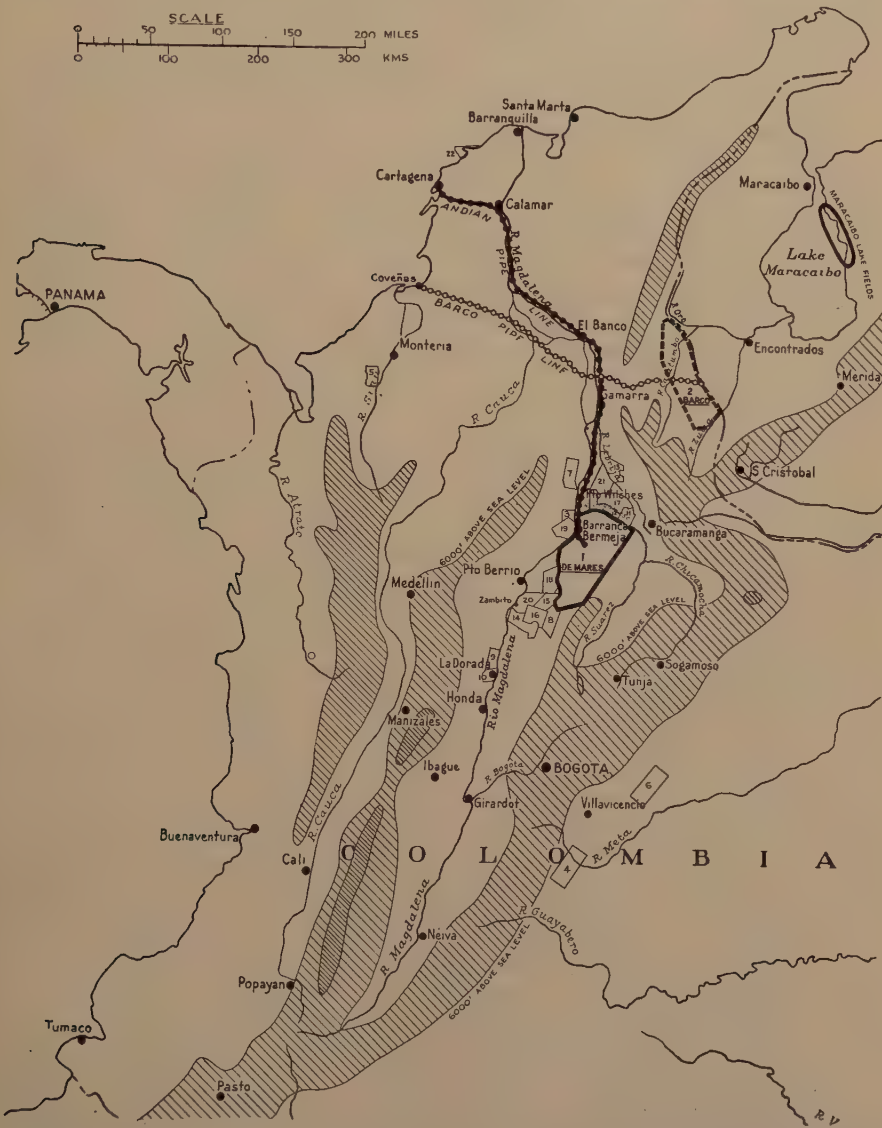

FIG. 1.—APPLICATIONS FOR LEASES ON NATIONAL LANDS IN COLOMBIA, 1931–1938.

4844 bbl. were completed in the Rio de Oro field. A wildcat well on the Leoncito faulted anticline was abandoned as a dry hole at a depth of 3045 ft. and at the end of the year a test well was drilling on the Carbonera fault zone at a depth of 1397 feet.

TABLE 2.—*Status of Applications*

Number on Fig. 1	Company	District	Date Accepted	Area, Hectares[a]
	APPLICATIONS ACCEPTED IN 1938 BUT CONCESSIONS NOT YET GRANTED			
3	Juan de Dios Gutierrez	Rio Cimitarra	Apr. 5	16,927
4	Compania de Petroleo Shell de Colombia	East Colombia	Aug. 1	100,000
5	Roberto Peña	Rio Sinu	Oct. 5	44,954
6	Texas Petroleum Co	East Colombia	Dec. 3	100,000
7	Richmond Petroleum Co	Rio Simiti	Mar. 15	49,000
8	Mora & Pelaez Hnos	Rio Minero	Mar. 16	42,336
9	Jaime Gutierrez	Buenavista	Dec. 5	49,199
10	Carlos de Narvaez	Buenavista	Dec. 5	36,015
11	Frederick R. Ryan	Rio Sogamoso	June 22	19,328
	APPLICATIONS ACCEPTED BEFORE 1938 BUT CONCESSIONS NOT YET GRANTED			
12	Socony-Vacuum Oil Co. of Colombia	Rio Sogamoso	Sept. 1, 1936	27,040
13	Sindicato de Inversiones, S. A.	Rio Lebrija	June 4, 1937	45,905
14	Evaristo Obregon	Rio Ermitano	July 9, 1936	42,546
	NATIONAL CONCESSIONS AWARDED 1931–1938			
			Date Awarded	
	Tropical Oil Co	Putana (Sogamoso)	Mar. 1, 1933	7,430
15	Sociedad Nacional del Carare (under joint exploration with Tropical Oil Co.)	Rio Carare	Sept. 22, 1936	33,476
16	Bernardo Mora Concession (transferred to Shell, Oct. 27, 1937)	Rio Carare	Sept. 28, 1937	50,000
17	Luciano Restrepo Concession (transferred to Socony Vacuum)	Rio Sogamoso	Sept. 19, 1934	49,232
18	Compania de Petroleo Shell de Colombia	Rio Carare	Mar. 2, 1938	49,906
19	Compania Colombiana de Petroleos, El Condor	Rio Cimitarra	Sept. 15, 1938	47,810
20	Consorcio Minero Nacional Concession (transferred to Shell, Mar. 3, 1938)	Rio Carare	Feb. 22, 1938	44,258
21	Compania de Petroleos del Carare	Rio Lebrija	Mar. 15, 1938	49,636
22	Compania de Petroleos El Libertador	Barranquilla	May 25, 1938	20,141

[a] Approximately 2.5 acres.

Socony Vacuum Oil Co.—The Socony Vacuum, which holds concessions covering a sizable area north of the Tropical property and between the Rio Sogamoso and the Rio Lebrija, was reported drilling on its deep test, Narino No. 1, at about 6500 ft. at the end of the year. Subsequently it was reported that this well was to be abandoned and another location was being prepared in the vicinity.

The company carried on extensive geological and geophysical work in the central and western part of this area, and in addition was active in investigating other parts of the Magdalena Valley and coastal area as well.

Tropical Oil Co.—During 1938 the Tropical completed a total of 111 new wells on the DeMares Concession, all but one of which were producers yielding an average initial production of approximately 435 bbl. The completions greatly exceed those for 1937, when only 70 wells were drilled. Production from the Infantas and La Cira fields totaled 21,581,588 bbl., of which 275,848 bbl. was petroleum condensate added to the crude. A Cretaceous test on the La Cira structure had reached a depth of 7983 ft. at the year's end. On the Putana Concession, well No. 2 was abandoned at 2793 ft., and well No. 3 at 7522 ft.

In conjunction with the Sociedad Nacional del Carare, the Tropical drilled San Fernando No. 1 to a depth of 4745 ft. before mechanical conditions made it advisable to shift the rig to another near-by location, where San Fernando No. 2 was spudded in on Dec. 28. In this same area, southeast of Puerto Berrio, the Shell company was drilling an exploratory well at Zambito, which had reached a depth of approximately 2000 ft. at the end of the year. It is understood that this well was subsequently abandoned at a slightly greater depth.

Petroleum Production in Cuba during 1938

By W. M. O'Connor* and Roy E. Dickerson,† Member A.I.M.E.

(New York Meeting, February, 1939)

The production of crude petroleum of the Bacuranao field, Cuba, fell off rapidly because no new wells were drilled. In December 1938, the total was 15 bbl. per day. The estimated average from this serpentine field for the year is 20 bbl. per day.

The Motembo area produced an estimated average of 160 bbl. per day. Production in July was 215,946 gal. of gasoline, or 165 bbl. per day. In August production was higher because a new well in the concession, the Luisa Marcela, produced 189 drums the first day and required pit storage.

The Atlantic Refining Company of Cuba started a deep test upon a long, narrow, surface-defined anticline 3 km. south of Remedios, a town on the north coastal plain of Santa Clara province, in December 1938. The Atlantic Refining Co. is doing extensive seismograph and gravity-meter work in Matanzas and Santa Clara provinces.

The Shell company was rigging for a deep test in western Havana province at a location about 2 km. west of the town San Antonio de los Banos.

New Petroleum Law

More serious attention was given by some of the major oil companies to the development of petroleum in Cuba as a result of the passage of a Petroleum Law in that country on May 9, 1938. Under the old mining laws of Cuba, which gave no special treatment to petroleum, the usual provisions giving reasonably satisfactory guarantees to encourage investment of foreign capital were either entirely lacking or were so ambiguously expressed as to require legislative action.

Under the new law, Government royalty is fixed at 10 per cent with the provision that it will be reduced to 9 per cent on crude petroleum that is refined in Cuba. Royalty to the surface owner is 1 per cent. A surface tax on a sliding scale from 10¢ to 40¢ per hectare per year is applicable to all exploitation concessions granted under the law or adapted to its provisions. No export tax is payable upon petroleum. Stability of taxation

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* Vice-president, Atlantic Refining Co., Philadelphia, Pa.

† Chief Geologist, Foreign Division, Atlantic Refining Co.

is assured by the stipulation that no alteration of rates established in the Law shall be made and no new taxes added during the life of concessions, except those of a general character affecting all industries alike.

The Petroleum Law authorizes the issuance of exploration concessions for a three-year term, without extension, provided an annual tax of 15¢ per hectare is paid. The area of each exploration concession is limited to 32,000 hectares. Exploitation concessions are granted for a period of 30 years, giving the concessionaire preferential right to renew a concession at the expiration thereof. The maximum area of an exploitation concession is 8000 hectares. Such concessionaires enjoy the right of expropriation of surface areas necessary for carrying forward their operations, right to enter upon properties for geological and geophysical work, right to construct all installations necessary for the several branches of the industry, Customs exoneration on material imported for a period of 10 years, as well as the right to import drillers and other technical workers.

On the other hand, the Petroleum Law requires that a National Reserve Area be set aside, representing one-eighth the total area demarcated for exploitation concessions already granted or which may be issued in the future. In addition, a continuous drilling obligation is imposed upon all exploitation concessions requiring the drilling of wells within periods varying from 5 to 10 years, depending upon the area of concessions. However, the grouping of concessions is permitted to facilitate compliance with this obligation.

Petroleum and Gas in Ecuador

By E. Escobar P.,* Member A.I.M.E.

(New York Meeting, February, 1939)

Table 1.—*Oil and Gas Production in Ecuador in* 1938

Line Number	Field, Santa Elena County, Province of Guayas	Age, Years to End of 1938	Area Proved, Acres: Oil	Area Proved, Acres: Oil and Gas[a]	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1938	Total Oil Production, Bbl.: During 1937	Total Oil Production, Bbl.: During 1938	Total Oil Production, Bbl.: Daily Average during Nov. 1938
1	El Tambo	7	x			7,538	778	1,577	4
2	Concepcion	8	x			68,365	8,440	10,100	25
3	Cautivo	16	2,xxx		2,xxx	P 161,134[1]	3,658	1,574	y
						W 271,007	24,413	50,004	y
						432,142	28,071	51,578	199
4	Ancon	18		12,000	12,000	H y[2]	1,70x,xxx	1,74x,xxx	y
						L y	36x,xxx	37x,xxx	y
						18,529,634	2,069,622	2,119,496	5,792
5	Carolina and Santa Paula	P 20[1]				P 355,997	37,587	26,516	y
		W 6	2,000	0	2,000	W 142,515	15,889	40,477	y
						498,512	53,476	66,993	161

Line Number	Total Gas Production, Millions Cu. Ft.: To end of 1938	During 1937	During 1938	Maximum Daily during 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Temporarily Shut Down	At End of 1938: Producing Oil Only	At End of 1938: Producing Oil and Gas[b]	At End of 1938: Total Producing	Depth, Average in Feet: Bottoms of Productive Wells	Depth: To Top of Productive Zone	Oil-production Methods at End of 1938, Number of Wells: Flowing	Pumping	Miscellaneous	Injection into Reservoir
1	x	x	x	x	6	3	0	0	6	0	6	1,200	yy	0	6	0	0
2	x	x	x	x	6	1	1	0	4	0	4	y	y	1	3	0	0
3	x	x	x	x	P y	0	y		y	0	y	30	28	2	79	Py[4]	0
					W 151	6	y	1	81		81	1,000	xxx				
4	x	2,xxx	2,145[3]	5.74	H 182	4	2	0	0	167	167	3,800	3,xxx	31	136	0	2G
					L 344	28	12		yy	2yy	289	1,200	1,xxx	0	289	0	0
					526	32	14			3yy	456			31	425		
5	x	x	x	x	P y	y	y		y		y	30	2x				
					W 40	1	0	0	29	0	19	600	xxx	1	28	Py[4]	0

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* Civil Engineer, General Inspection of Mines, Petroleum Zone, Libertad, Ecuador.

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d] Average at End of 1937	Pressure, Lb. per Sq. In.[d] Average at End of 1938	Character of Oil Approx. Average during 1938: Gravity A.P.I. at 60° F. Weighted Average	Sulphur, Per Cent	Base[5]	Producing Rock: Name	Age[e]	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Number of Dry and/or Near-dry Holes to End of 1938	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
1	*x*	*x*	34	*y*	Naph.	Socorro(?)	Eoc	S	Por	*x*	*y*	0	Socorro	1,300
2	*x*	*x*	38	*y*	M	Socorro(?)	Eoc	S	Por	*x*	*y*	2	Atlanta sandstone	3,500
3	*x*	*x*	P 18 W32	*y*	M	P *y* W Socorro	Olig and recent Eoc	Ss S	Por	P 6 W3,*xxx*	H *y*	*y* 70	Atlanta sandstone	3,993
4	H1,050 L *x*	1,050 *x*	41 36	 *y*	P Naph.	Atlanta Socorro	Eoc Eoc	S SH	Fis Por	2,500 200–1,000	AF *y*	12 58	San José sandstone	8,053
5	*x*	*x*	P 18 W28	*y*	M	P *y* W *y*	Olig and recent Eoc	Ss S	Por	P 5 W *xx*	H *y*	*y* 11	Seca sands(?)	1,050[6]

[a] Footnotes to column heads and explanation of symbols are given on page 240.
[1] In the same area there are many shallow pits and some wells. These are indicated by P and W.
[2] H means the deep zone at 3,800 ft. for "High Cold Test" crude oil; L means the shallow zone at 1,200 ft. for "Low Test" crude oil. They occur in the same area.
[3] Gal. gasoline per M cubic foot: H, 0.88; L, *y*.
[4] The crude oil from the shallow pits is collected in cans and poured into wooden barrels, which are rolled to small storage tanks.
[5] P, paraffin; M, mixed.
[6] Still drilling.

Production of Oil in Egypt in 1938*

(New York Meeting, February, 1939)

AT the end of June, 1938, a new oil field was opened in Egypt, the Ras Gharib. Five wells were completed during the year and gave a total production of 512,988 barrels.[1] In the Hurghada field production was as follows:

HURGHADA FIELD

Age of field to end of 1938, years	25
Producing area for gas and oil, acres	1,050
	BARRELS[1]
Total oil production to end of 1938	31,207,754
Total oil production during 1937	1,141,356
Total oil production during 1938	1,019,520
Average oil production per acre to end of 1938	29,719
Average oil production per acre-foot to end of 1938	243.6
Daily average production in December 1938	2,603.54
Daily average production per well in December 1938	34.90
	MILLIONS CU. FT.
Total gas production (Aug. 1925 to end of 1938)	4,356.7
Total gas production during 1937	222.5
Total gas production during 1938	167.6
Maximum gas daily average of 1938 (in May)	0.6
	WELLS
Number of producing wells completed to end of 1938	100
Number of producing wells completed during 1938	3
Number of wells abandoned during 1938	2
Producing wells at end of 1938 (all pumping)	78
Abandoned wells at end of 1938	22
Dry wells at end of 1938	21
	FEET
Average depth of bottom of producing horizon	1,720
Average depth of top of producing horizon	1,598

Character of oil, approximate average in 1938: specific gravity at 60° F., 0.900; base, mixed.

Character of gas, approximate average for 1938: gallons gasoline per 1000 cu. ft. of gas, 6.4.

Main producing formation: Nubian sandstone, Cretaceous (?); sand rock and sandstone.

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* Information received through the courtesy of the Controller of the Egyptian Department of Mines and Quarries, Dawawin P. O., Egypt. Manuscript received at the office of the Institute Feb. 11, 1939.

[1] Figures were given in E. tons. A conversion factor of 6.98, based on 0.900 sp. gr., was used to obtain the number of barrels.—Ed.

Petroleum in France and French Colonies

By H. de Cizancourt*

Table 1.—*Oil and Gas Production in France and French Colonies*

Line Number	Field, *Department*	Age, Years to End of 1938	Area Proved, Acres: Oil	Area Proved, Acres: Gas	Area Proved, Acres: Total	Total Oil Production, Bbl.[1]: To End of 1938	Total Oil Production, Bbl.[1]: During 1937	Total Oil Production, Bbl.[1]: During 1938	Total Oil Production, Bbl.[1]: Daily Average during Nov. 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Producing Oil Only	At End of 1938: Total Producing
	France:													
1	Pechelbronn, *Bas Rhin*	203	7,462			15,146,586	491,750	502,649[2]	1,400	Approx. 4,050	70	21	701	701
	Morocco:													
2	Bon Draa { BO2, BO4, BO11, BO22, BO24	2	222	18.5	240.5		17,199 (lines 2 and 3)	27,706 (lines 2 and 3)		26	9			
3	Tselfat { Ts26 bis, Ts35, Ts36, Ts37, Ts40, Ts43	2			39.5					43	5			
	Algeria:													
4	Tliouanet	27						1,820						

[1] Original "tons" converted on ratio of 1 ton = 7 barrels. [2] 291,207 bbl. by wells, 211,442 bbl. by mining.

Line Number	Depth, Average in Feet: Bottoms of Productive Wells	Depth: To Top of Productive Wells	Number of Wells: Flowing	Number of Wells: Pumping	Number of Wells: Repressuring	Mining	Gravity A.P.I. at 60° F.: Maximum	Gravity: Minimum	Gravity: Weighted Average	Sulphur, Per Cent	Base	Producing Formation: Name	Age[e]	Character[f]	Net Thickness, Average in Feet	Structure[g]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
1	1,322	820–3,051		690	11	3 shafts	0.950	0.850	0.880	0.03	P	Olig to Triassic	Olig, Jur, Ervasoc	SD		AF	Permian and granite	5,151
2	3,114	465		x								Limestone	Toarcian					
	609	570		x								Limestone	Toarcian					
	633	540		x								Limestone	Toarcian					
	954	750	x									Limestone	Toarcian					
	477	420		x								Limestone	Toarcian					
3	744	714	x									Limestone	Domerian		15		Domerian	
	651	627	x									Limestone	Domerian		15		Domerian	
	789	732		x								Limestone	Domerian		15		Domerian	
	867	770		x								Limestone	Domerian		15		Domerian	
	732	699		x								Limestone	Domerian		15		Domerian	
	345	270		x								Toarcian limestone	Toarcian		15		Toarcian	
4																		

[a] Footnotes to column heads and explanation of symbols are given on page 240.

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* Compagnie Française des Pétroles, Paris, France.

TABLE 2.—*Summary of Drilling Operations in France and French Colonies*

Important Wildcats Drilled in 1938

	Country	Location		Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Remarks
		Lat.	Long.					
	France:							
1	Pic St. Loup	43° 45′ N.	3° 50′ E.	drilling	Liassic	Domerian		
2	St. Marcet	43° 7′ N.	0° 45′ E.	drilling				
3	Pezenas	43° 30′ N.	3° 30′ E.	3,792				Dry hole
4	Gornies			drilling				
	French Equatorial Africa:							
	Yeno	1° 45′ S.	9° 30′ E.	3,290	Sands Cenomanian(?)	Grey limestone Aptian(?)	Syndicat d'études et de recherches petrolières	Dry hole
	Madagascar							
6	Ambohidr anomora	19° 30′ S.	45° E.	3,182		Sandstone, Triassic (?)	Syndicat d'études	Dry hole
	Marec:							
7	Daharen Nsour			2,572	Domerian (Jurassic)	Salt (Triassic)	Syndicat d'études	Dry hole
8	Djebel Harricha			4,954	Pliocene	Helvetian	Syndicat d'études	Dry hole
9	Bou Mimoun			7,274	Pliocene	Cretaceous marks	Syndicat d'études	Dry hole
10	Mohamed Chleuh	About 34° 20′ N. and 5° 45′ W. Greenwich		2,368	Cretaceous marls	Triassic salt	Syndicat d'études	Dry hole
11	Karia			1,132	Cretaceous marls	Eocene marls	Syndicat d'études	Dry hole
12	Gueddara			8,261	Cretaceous marls	Domerian limestone	Syndicat d'études	Dry hole
	Tunisia:							
13	El Haroune			7,352	Sahelian	Lutetian marls	Syndicat d'études	Dry hole
14	Zaouia	37° 5′ N.	9° 50′ E.	2,582	Causmanian	Aptian marls	Syndicat d'études	Dry hole
15	Rhazaouane	35° N.	9° 30′ E.	2,854	Barremian marls	Barremian	Syndicat d'études	Dry hole
		36° 20′ N.	9° 10′ E.					

Petroleum Development in Germany during 1938

By Walter Kauenhowen*

The crude-oil production of Germany without Austria during 1938 amounted to 3,864,518 bbl., representing an increase of 21.7 per cent over the 3,173,373 bbl. produced in 1937. Adding the Austrian production, the crude-oil production of the new German Reich totaled 4,259,717 bbl. during 1938, representing an increase of 25.3 per cent compared with the respective figures of the previous year.

According to published official data, and using a conversion factor of 1 metric ton equaling 7 bbl., the oil production of Germany in 1938 was as shown in Table 1.

Table 1.—*Oil Production in Germany*

Field	Production in 1938, Bbl.	Percentage of Total German Production, 1938	Percentage of Increase or Decrease Compared with 1937
Nienhagen	2,507,330	58.8	+ 3.3
Wietze	304,136	7.1	− 2.9
Oberg	118,321	2.8	− 21.0
All other fields of the Altreich	934,731	22.0	+230.9
Total	3,864,518		+ 21.7
Ostmark	395,199	9.3	+ 70.8
Grand total	4,259,717	100.0	+ 25.3

A semiofficial publication[1] states that the program of the crude-oil industry for the second year (1938) of the four-year plan was successfully accomplished. According to the same source, new drilling developments at the following localities were promising: Reitbrook near Hamburg, Heide in Holstein, Eicklingen-Sandlingen near Celle, Steimbke near Nienburg, Worms in the Rhine Valley, Gifhorn near Braunschweig, Mölme near Oberg, and at other places. The drilling activity for oil is illustrated by the figures in Table 2.

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* Deutsche Vacuum Oel A. G., Hamburg, Germany.

[1] *Ztsch. Oel und Kohle* (1938) No. 46, 1059–1064.

TABLE 2.—*Drilling Operations in Germany*

Year	Total Meters Drilled for Oil	Meters Drilled in Productive Fields	Meters Drilled by Wildcat Wells	
			With Government Subsidy	Without Government Subsidy
1932	62,384.32	49,330.07		13,054.25
1933	84,053.85	54,088.01		29,965.84
1934	141,848.03	74,915.69	37,239.27	29,693.07
1935	172,523.29	99,230.78	52,884.98	20,407.53
1936	179,297.60	91,337.96	66,167.35	21,792.29
1937	204,348.15	85,364.86	35,244.61	16,970.30
1938[a]	220,000.00	90,700.00	57,700.00	41,600.00

[a] Estimated.

About half of the meters drilled during the last few years were drilled by wildcat wells, two-thirds of which were subsidized by the Government.

The total accumulated oil production of Germany from 1872 up to and including September 1938 amounts to 5.05 million tons, or about 35,000,000 bbl., of which 53 per cent was produced from 1872 to 1932 and 47 per cent from 1933 to September 1938.

The deepest well drilled for oil in Germany during 1937 was Wienhausen No. 10, near Celle, with a total depth of 3400 m. (11,152 ft.). The deepest well in 1938, Holstein No. 14, near Heide, was abandoned at a total depth of 3818 m. (12,523 ft.).

Search for Oil in Great Britain

By A. H. Taitt*

(New York Meeting, February, 1939)

During 1938, the exploratory drilling by the D'Arcy Exploration Co. Ltd., subsidiary of the Anglo-Iranian Oil Co. Ltd., was continued. The original basis of the search for oil and results to the end of 1937 have already been described.[1] During 1938 two further wells were drilled in the south, making a total of five wells completed in that part of England. Test wells were also commenced in the Midlands, East Yorkshire and Scotland, where one well, which proved natural gas, was completed during the year.

Southern England.—The test well at Kingsclere, in Hampshire, which at the end of 1937 had reached a depth of 5032 ft. in the Lower Lias, entered the Trias at 5060 ft. and was abandoned in that formation at a depth of 5125 ft. A shallow test well was also drilled near Pevensey, in Sussex, to test the lower horizons of the Wealden series and the Purbeck and Portland beds. Traces of oil were encountered in the Wealden series but no production was obtained and the well was abandoned at a depth of 842 ft. in the Kimeridge clay, which underlies the Portland beds.

A geological borehole was begun north of Lulworth in Dorset, where the outcropping Wealden series, Lower Cretaceous, is strongly impregnated with oil, to determine whether a more pronounced pre-Albian anticline underlies the very gentle arch of the unconformable Upper Cretaceous. Drilling is not yet completed.

Nottinghamshire, Lincolnshire and Yorkshire.—Geophysical investigations were continued in the eastern part of England where the structural conditions of the Carboniferous rocks are concealed by an unconformable blanket of Permian and younger sediments. Seismic methods failed to confirm the structural picture obtained by the previous gravity traverses, but confirmation of a structure near Ollerton, Nottinghamshire, which was suspected on evidence from colliery workings, was obtained. A location was made for a test well on this structure.

Eskdale No. 1, begun on the Eskdale pericline near Whitby, in Yorkshire, to test the magnesian limestone of Permian age, was abandoned at a depth of 2486 ft. in the Trias after protracted fishing operations. A

Manuscript received at the office of the Institute Feb. 10, 1939.

* D'Arcy Exploration Company, Ltd., London, England.

[1] *Trans.* A.I.M.E. (1937) **123**, 579; (1938) **127**, 660.

second well, approximately 100 ft. from the first, entered the upper limestone of the Permian at 4196 ft., and had reached a depth of 4204 ft. by the end of the year.

Midlands.—A site was selected in 1937 at Gun Hill, in North Staffordshire, to test the lower Carboniferous limestone as a possible source of oil; it was in this limestone that oil was found at Hardstoft in Derbyshire in 1919. At Gun Hill the lower Carboniferous limestone was entered at 1535 ft. Cores from the shales and thin limestones overlying the main limestone showed abundant evidences of oil but the limestone itself was barren and on test produced only slightly saline water with a specific gravity of 1.003. Drilling was continued to 3861 ft. during the year. It was considered possible that thick shales might be developed in the lower Carboniferous and that production might be secured from limestones at lower horizons, but deepening proved this supposition erroneous and showed little further prospect of obtaining commercial production. Drilling was continued, however, principally to secure information of geological value.

The Hardstoft well, which had a pumping production of approximately one ton of oil a week, was reconditioned, deepened to 3272 ft. from 3127 ft., and acid-treated. Extensive production tests have not yet been carried out but reservoir connection is greatly improved as a result of the acid treatment.

A series of shallow holes was drilled in the seepage area of Coalport-Coalbrookdale in Shropshire, to determine the origin of the seepage oil. The results of these boreholes showed that the oil is confined to the thin and only locally developed Coal Measures of the upper Carboniferous.

Scotland

The well to test the oil-shale group of the lower Carboniferous was completed at a depth of 2917 ft. on the D'Arcy-Cousland anticline near Edinburgh. Several promising sands were drilled through and drill-stem tests proved a natural-gas production of over 10 million cubic feet per day with a small showing of oil. A second well, sited approximately 200 ft. structurally lower than the first, had reached a depth of 616 ft. by the end of the year. A third well was located 2 miles north of the first, to prove the northerly extension of the structure, and drilling will commence early in 1939.

In Fifeshire four shallow boreholes were drilled for structural information on which to base a decision to drill with an objective similar to that at Cousland.

The first of a series of shallow boreholes to determine the nature of the Pentland fault, in which Devonian rocks are faulted against rocks of Carboniferous age, was commenced at the end of the year. The

Pentland fault forms the western boundary of the Midlothian Carboniferous basin, on the eastern side of which is the D'Arcy-Cousland anticline.

Drilling by Other Companies

Three other companies, the Anglo-American Oil Co. Ltd., the Gulf Exploration Co. Ltd. (Great Britain) and Steel Brothers & Co. Ltd., were also carrying out geological and geophysical work and test drilling in Britain during 1938. For the following details of the operations of the two latter companies I am indebted to the companies concerned, who have kindly provided me with the necessary information.

The Gulf Exploration Company (Great Britain) Ltd. drilled a well at Penshurst, in Kent, after a seismic investigation of the structure, to a depth of 5600 ft. during 1938. The well was started at the end of May in Lower Cretaceous strata and after traversing a normal series of Jurassic and Rhaetic entered the Carboniferous at a depth of 4630 ft. The well was abandoned after drilling difficulties in September, in limestones of the lower Carboniferous. No gas or oil shows of importance were encountered. Geophysical (seismic and gravimeter) investigations, accompanied by surface geological work, were also carried out by this company in southern and western England and in the Cleveland Hills in Yorkshire. The latter investigations are being continued.

Steel Brothers and Company Ltd. completed a well begun in 1937, on the northern end of the Derbyshire dome near Edale. They drilled to 757 ft. in the lower Carboniferous limestone but found it watered and abandoned the well in October 1938. During the course of drilling gas was struck at 126 ft., having a pressure of about 20 lb. per sq. in. and a volume of 4000 cu. ft. per day. The gas was mostly methane with a little ethane and a smell of sulphuretted hydrogen. This gas was exhausted in a few days. There was a smell of oil at 126 ft., a spot of oil on a joint plane at 291 to 296 ft., a show of oil on the first water 346 to 370 ft., a spot of brown oil in a fissure 585 to 588 ft., spots of green oil and brown elaterite 602 to 606 ft. and again spots of green oil at 617 to 618 ft. and 637 to 641 feet.

Petroleum Developments in Hungary and Czechoslovakia in 1938

By Brandon H. Grove*

(New York Meeting, February, 1939)

Hungary

The rapid development of the Budafa-Puszta field during 1938 advanced Hungary a considerable distance along the road to self-sufficiency in domestic crude-oil supplies. Seven wells were completed in the field during the year, at depths averaging 4100 ft., and there have been no dry holes. Initial productions have ranged from 150 to about 400 bbl. per day. At the end of the year daily average production amounted to about 1400 bbl., which is equivalent to 33 per cent of Hungary's daily internal consumption.

Production increased somewhat in the Government-controlled oil field at Bükkszek, also discovered in 1937, but nothing occurred to alter previous indications that this field would be capable of only relatively insignificant development. A further test of the Miocene-Oligocene basin containing the Bükkszek field is being made by a well now drilling

Table 1.—*Oil and Gas Production in Hungary and Czechoslovakia*

Line Number	Country, *Field*	Age, Years to End of 1937	Area Proved, Acres				Total Oil Production, Bbl.[1]			
			Oil	Oil and Gas	Gas	Total	To End of 1938	During 1937	During 1938	Daily Average during Nov. 1938
1	Czechoslovakia, *Gbely* (*Egbell*)	25		200	y	200	1,648,445	93,618	107,586	y
2	Czechoslovakia, *Hodonin* (*Göding*)	19		165	y	165	870,233	31,890	26,465	y
3	Hungary, *Bükkszek*	2	192	0	0	192	50,364	9,300	41,064	237
4	Hungary, *Budafa-Puszta*	2		1,200	25	1,225	293,630	9,843	283,787	1,371

[1] Converted from metric tons at average specific gravity of crude.

Manuscript received at the office of the Institute Feb. 14, 1939.

* Socony Vacuum Oil Co., Inc., The Hague, The Netherlands.

at Recsk. In December this well had reached 1600 ft. in the Lower Rupelian (Middle Oligocene) without important shows.

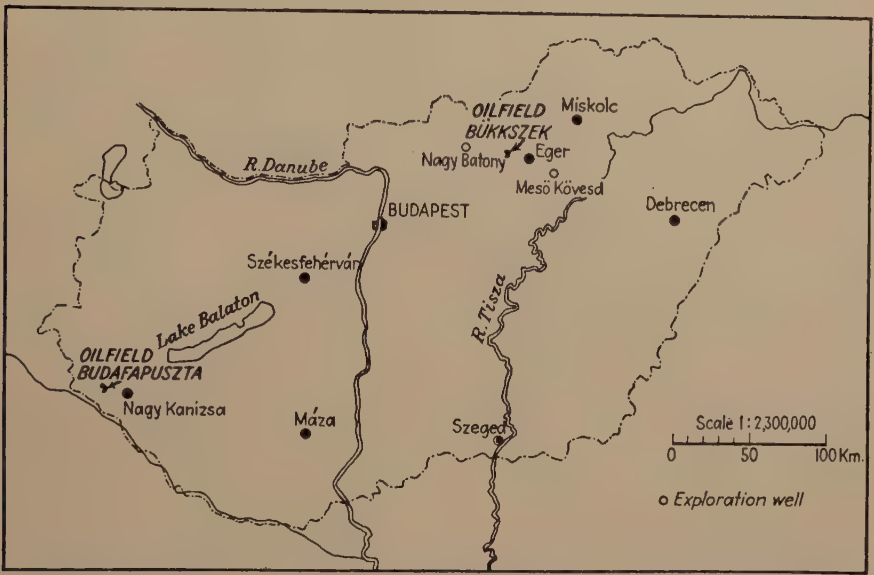

FIG. 1.—LOCATIONS OF NEW HUNGARIAN OIL FIELDS AND WILDCATS IN PROCESS OF DRILLING.

The success at Budafa-Puszta encouraged the Government to resume its exploratory drilling in the Great Hungarian Plain east of the Danube, and at the close of the year State wildcats were drilling at Nagybatony and at Mezökövesd (Fig. 1).

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.: To End of 1938	During 1937	During 1938	Maximum Daily during 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Temporarily Shut Down	At End of 1938: Producing Oil Only	At End of 1938: Producing Gas Only	At End of 1938: Total Producing	Depth, Average in Feet: Bottoms of Productive Wells	To Top of Productive Zone	Oil Production Methods at End of 1938, Number of Wells: Flowing	Pumping	Bailing	Pressure, Lb. per Sq. In.[d]: Initial	Average at End of 1937	Average at End of 1938
1	27y	7	y	y	38y	2y	y	1y	5y	y	y	790	540	y	0	y	y	x	x
2	y	46	y	y	12y	y	y	y	y	y	1y	485	425	y	y	y	y	x	x
3	0	0	0	0	35	21	13	0	12	0	12	340	335	0	8	4	40	30	30
4	590	325	558	25	10	9	0	1	8	0	8	3,805	3,674	8	0	0	1,050	y	y

[d] Footnotes to column heads and explanation of symbols are given on page 240.

Maort Operations

During 1938 the Budafapuszta field was further developed by the completion of seven oil wells and one gas well, which brought the area proved for oil and gas up to 1196 acres. At the end of 1938, seven out of the total of ten wells completed to date were producing 1500 bbl. a day.

The small gas well completed during 1938 is located about 1½ miles east of Budafapuszta No. 4. It is capable of producing 300,000 cu. ft. of gas daily.

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1938: Gravity, A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[2]	Character of Gas, Approx. Average during 1938: B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Producing Formation: Name	Age[e]	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]	Number of Dry and/or Near-dry Holes to End of 1938	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
1	40	20	21	0.25	A, P	y	y	Sarmat Torton	Mio	SH	y	23	AF	7y	Flysch (Eocene?)	5,122
2	40	18	27	y	A	y	y	Sarmat	Mio	SH	y	25	AF	3y	Mediterran (Mio)	2,411
3	40	31	34	0.50	P	y	y	Repelian	Olig	SH	y	18	AF	18	Carboniferous	2,296
4	y	y	40	y	P	y	1	Pannon	Pli	SS	25	75	A	0	Sarmat	5,799

[2] A, asphalt; P, paraffin.

TABLE 2.—*Summary of Drilling Operations in Hungary and Czechoslovakia*

Important Wildcats Drilled in 1938

	Country, *District*	Location: Lat.	Location: Long.	Total Depth, Ft.	Surface Formation	Deepest Horizon Tested	Drilled by	Remarks
1	Hungary, *Transdanubia*	46°30′	16°45′	4,920	Pliocene	Upper Miocene	Maort	Testing shows in Lower Pannonian
2	Hungary, *Alföld*	47°35′	20°40′	2,296	Quaternary	Upper Miocene	Government	Dilling in Sarmat
3	Hunhary, *Alföld*	48°55′	20°30′	3,000	Quaternary	Lower Oligocene	Government	Drilling in Lower Oligocene

	Wells	Hungary: In Proven Fields	Hungary: Wildcats	Czechoslovakia: In Proven Fields	Czechoslovakia: Wildcats
	Number of wells drilling December 31, 1938	4	3	y	0
	Number of oil wells completed during 1938	15	0	2y	0
	Numper of gas wells completed during 1938	1	0	y	0
	Number of dry holes completed during 1938	13	0	y	1

One dry hole was drilled by Maort, the Mihalyi No. 2. This well reached a total depth of 8226 ft. and tested a small amount of carbon dioxide before it was abandoned.

Czechoslovakia

Production in Czechoslovakia was essentially static during 1938. In the last months of the year the Apollo company succeeded in finding a southern extension to the producing area of the Hodonin field, which promises to materially increase its production. Production in the Government-owned Gbely field increased moderately as the result of successful wells within the proved area.

Work was actively begun on the oil-mining project at Sokolnice, near Brno (Brünn), and at the end of December a mine shaft had been sunk to 120 ft. (projected depth about 260 ft.). Work has also begun on equipment for refining the oil sand as it is mined. It is reported that an experimentally successful process has been devised for refining the crude directly from the sand.

Petroleum in India and Burma in 1937

(New York Meeting, February, 1939)

The production of petroleum in India (including Burma) increased from 334,811,624 gal.[1] in 1936 to 350,322,222 gal. in 1937, the highest figure in the history of the industry. The increase in 1937 was due to an increase of some 20 million gallons from Singu, 5½ million gallons from Attock, 1¼ million gallons from Thayetmyo, and 1 million gallons from Digboi, accompanied by decreases of 9½ million gallons from Yenangyaung and 2 million gallons from Yenangyat.

The amount of gasoline produced from natural gas during the year was 10,616,313 gal. in Burma and 456,780 gal. in the Punjab.

Yenangyaung Field.—The Yenangyaung field maintained its reputation of being one of the most wonderful oil fields in the world. The total production during 1937 was less than in the previous year but the resources of the field as a whole are sufficient to ensure an adequate supply of oil for many years. At the end of 1937 there were 2910 wells producing in the field. Besides a large number of wells drilled to shallow sands, this total includes 180 hand-dug wells, whose continued existence is one of the interesting features of the field.

During the year the deep drilling activities of 1936 in the southern part of the field died down, owing to the disappointing results obtained. On the eastern flank the limit of present economic extension of the oil sands was approximately demarcated.

Satisfactory results continue to be obtained from gas drives in the leased blocks; gas is also injected for repressuring and storage. Casing policies continue to be carefully designed to protect the oil sands against the danger of flooding by water and, in general, production methods throughout the field are characterized by a realization of the importance of the conservation of oil and gas and the prevention of waste, whether simple or underground.

Singu Field.—In 1937 the increase in the output from the Singu field was continued. This increased production was due not only to the rapid development of the valuable area in the southern part of the field but also to the successful results obtained from the first wells to produce from behind the practically completed river training wall of the Burmah Oil

Reprinted from the Records of the Geological Survey of India, volume 73, pages 44–49, by permission of the Director of the Geological Survey of India. (The report for the year 1938 is not yet available.)

[1] Imperial gallons throughout this paper.

Co. At the end of the year the total number of producing wells was 568 as compared with 480 in December 1936. In addition, a number of wells remained cemented above productive sands. These wells can be drilled into productive sands in a very short time and the total field production substantially increased.

There has been no radical change in production methods during the year under report. The fundamental principle underlying the policy of the major operating company at Singu is to make adjustments at each well that lead to a maximum oil recovery with a minimum production of gas. Wells with high gas-oil ratios are shut in, and the casinghead gas remaining after the satisfaction of the field requirements is returned to dry gas sands for storage, or to certain areas for repressuring purposes. The repressuring operations of the British Burmah Petroleum Co., Ltd., continued to give satisfactory results. The dry gas produced from the new gasoline-extraction plant is either used in connection with these schemes or as fuel. Continuous gas lift on some well producing from lower division sands and gas displacement pumping on wells producing from upper division sands were continued on small scale, but production from the great majority of the wells in the field was obtained by ordinary pumping methods.

TABLE 1.—*Quantity and Value of Petroleum Produced in India and Burma during the Years* 1936 *and* 1937

Fields	1936		1937	
	Quantity, Gal.	Value, Pounds	Quantity, Gal.	Value, Pounds
India:				
Assam:				
Digboi	64,844,712	£ 832,542	65,718,437	£ 843,760
Punjab:				
Attock	4,396,792	82,646	9,939,420	186,831
Total	69,241,504	915,188	75,657,857	1,030,591
Burma:				
Kyaukpyu	13,402	3,736,805	12,437	4,474,147
Minbu	3,666,403		3,418,311	
Singu	99,913,727		119,858,608	
Thayetmyo	712,455		2,001,180	
Upper Chindwin	2,815,672		2,502,140	
Yenangyat (including Lanywa)	27,147,566		25,067,655	
Yenangyaung	131,300,895		121,804,034	
Total	265,570,120	3,736,805	274,664,365	4,474,147

Yenangyat Field.—Although during 1937 active development continued at Yenangyat, the results obtained were somewhat disappointing and a decline in the total production from the Pakokku district, excluding Lanywa, was reported. Because of the large new production obtained from the Singu fields, the production from the Lanywa field during 1937 was still further restricted. An inclined well was commenced during the year to tap the known oil sands beneath the Irrawaddy River. Back pressures are maintained on nearly all the wells in this model field, which is operated by the Indo-Burma Petroleum Co., Ltd. While a number of wells are pumped from a central power, the majority have individual pumping motors. The gasoline plant was operated throughout the year and gave a satisfactory yield.

Minbu District.—In the Minbu district at the close of the year there were 374 producing wells. The total production showed little change. Apart from routine production there was very little activity in the district during the year.

Indaw Field.—There was a welcome increase during 1937 in the total production from the Indaw field. All producing wells were successfully operated by the automatic gas-lift system.

Thayetmyo District.—In the Thayetmyo district, while there was a slight decrease in production in the Padaukpin field, that of the Yenanma field showed a considerable increase. An extension of the known producing area was proved in this field. During the year, the Burmah

TABLE 2.—*Imports of Kerosene Oil into India during the Years* 1936 *and* 1937

From	1936[a]		1937[b]	
	Quantity, Gal.	Value, Pounds	Quantity, Gal.	Value, Pounds
Union of Socialist Soviet Republics	43,451,896	£ 933,726	27,377,419	£ 686,405
Rumania	286,000	7,442	308,000	8,006
Iran	6,189,381	97,299	8,218,665	227,595
Burma			93,466,680	2,840,037
Sumatra	8,242,365	262,865	27,955,437	647,049
United States of America	185,021	11,766	3,011,333	48,904
Other countries	868,621	37,534	2,512,597	58,833
Total	59,223,284	1,350,632	162,850,131	4,516,829

[a] Figures relate to India and Burma.

[b] Figures include imports to Burma during January to March 1937. The total quantity of kerosene oil imported into Burma during the year 1937 was 1,215,505 gal., consisting of 880,000 gal. from foreign countries and 335,505 gal. from India, including 8204 gal. of foreign oil.

Oil Company's deep test well at Monatkon was abandoned at 8319 ft., as no productive sand had been encountered.

Kyaukpyu Field.—The output from Kyaukpyu remained at its usual low level.

Digboi Field.—In Assam, output of the Digboi field increased slightly. There has been no drilling in outside areas in the Assam Valley.

Surma Valley.—In the Surma Valley there was no production. A final test of the well at Masimpur showed that the horizons penetrated were of no value and the well was abandoned. The results of this well indicated that the structure underground was not as would be expected from the surface evidence, and resistivity observations were therefore carried out and a large number of holes were drilled on both flanks of the anticline to obtain geological evidence from the rocks hidden beneath the alluvium. The results of this work again showed that unexpected structural complications occur and at the end of the year seismic observations were about to start in a further attempt to ascertain the shape of the structure at depth. In addition, it is proposed to drill a deep hole in order to obtain cores from a considerable depth.

The Punjab.—In the Punjab the Attock Oil Co., Ltd., operated the Khaur and Dholian fields. In the Khaur field the deep test for the limestone was successfully cemented and is at present at 5440 ft. in limestone formation and is being tested. Results however are disappointing, as the well is showing a considerable quantity of water with only a small quantity of oil and it does not promise to be an important producer. Shallow drilling has continued but has given only moderate results.

Dholian Field.—In the Dholian field two deep wells were brought on to production in May and November 1937, respectively, which have been steady producers. In the Board's report dated Feb. 2, 1938, these wells

TABLE 3.—*Imports of Fuel Oils into India during the Years* 1936 *and* 1937

From	1936[a]		1937[b]	
	Quantity, Gal.	Value, Pounds	Quantity, Gal.	Value, Pounds
Union of Socialist Soviet Republics	3,456,847	£ 36,425		
Iran	104,798,306	1,126,961	97,611,519	£ 962,927
Borneo (British)	10,549,735	155,020	13,050,640	200,593
Borneo (Netherlands)	12,318,009	150,234	5,426,441	73,762
Other countries	5,731,554	64,112	11,720,456	149,781
Total	136,854,451	1,532,752	127,809,056	1,387,063

[a] Figures relate to India and Burma.

[b] Figures include imports to Burma during January to March 1937. The total quantity imported into Burma during the year 1937 was 25,702,623 gallons.

were reported as producing 480 and 640 bbl. of oil per day, respectively. At the date of writing, the former is producing about 454 bbl. and the latter 480 bbl., but the fall in the second well, to a very considerable extent, is due to a reduction in size of bean from 5⁄16 to under 1⁄4 in., resulting in restriction of flow. This restriction is considered advisable partly from a storage point of view and partly in the interests of economical recovery of production.

Developments at other drilling wells are as follows: A well encountered a good show of black oil at 6200 ft.—probably worth 50 bbl. per day—but is being carried down to the deep horizon of the two main producers. Another well, which did not get black oil in any appreciable quantity, has been drilled to 7553 ft. and is being cemented. Another well has reached the depth of 3020 ft. New sites have been selected for additional wells.

TABLE 4.—*Exports of Paraffin Wax from India during the Years* 1936 *and* 1937

To	1936[a]		1937[b]	
	Quantity, Tons[c]	Value, Pounds	Quantity, Gal.	Value, Pounds
United Kingdom	17,367	£ 555,181	9,400	£315,840
Germany	165	5,211		
Netherlands	4,335	138,597	994	31,451
Belgium	2,465	78,526	974	30,870
Italy			860	27,166
China	1,277	40,282	1,841	52,333
Union of South Africa	2,753	86,782	1,903	54,858
Portuguese East Africa	4,259	134,462	2,085	60,493
Canada	2,044	64,442	835	26,368
United States of America	190	6,000	755	24,105
Mexico	1,500	48,158	2,475	89,066
Columbia	3,354	107,882	1,254	39,588
Chile	2,300	72,631	650	20,526
Australia	740	23,463	127	4,011
Other countries	976	30,319	1,294	43,036
Total	43,725	1,391,936	25,447	819,711

[a] Figures relate to India and Burma.

[b] Figures include exports from Burma during January to March 1937.

[c] Long tons.

Petroleum and Gas in Iran during 1938

(New York Meeting, February, 1939)

Masjid-i-Sulaiman.—There have been no new developments in the Masjid-i-Sulaiman oil fields during the year 1938. In spite of the age of this field, the fall in dome pressure shows no appreciable variation from the low rate of about 0.3 lb. per sq. in. per million tons net production. Drilling has been limited to deepening old wells and to new wells required for maintenance of production and general reservoir control. The rate of offtake has been reduced over the past few years, partly because of depletion of the oil column, and it is expected that future offtake from the Masjid-i-Sulaiman field will be stabilized for some years at around the present figure of 3,000,000 tons per annum.

Haft Kel.—An exploratory well to test deeper formations in the Haft Kel field has proved the existence of productive conditions in the Eocene, which underlies the Asmari limestone (the main producing horizon). Drilling to the northwest in the white-oil springs area has revealed the presence of a separate structure with productive potentialities. One well with a satisfactory production rate has been completed. Offtake from the Haft Kel field has steadily increased since it first came on to production in 1929.

TABLE 1.—*Production of Crude Oil in Iran*

Year	Masjid-i-Sulaiman[a]		Haft Kel		Total	
	Tons	Barrels[b]	Tons	Barrels	Tons	Barrels
1937	4,375,112	33,110,000	5,693,849	43,480,000	10,068,961	76,590,000
1938[c]	3,562,000	27,240,000	6,638,000	49,990,000	10,200,000	77,230,000

[a] Net production; i.e., excluding surplus products reinjected to reservoir.

[b] To nearest 10,000.

[c] Actuals to November with an estimate for December. To nearest 1000 tons.

Naft-i-Shah.—Production from this field has continued to supply market requirements in northwest Iran. The policy of returning surplus products to the reservoir, which was adopted at the beginning of 1936, has been continued.

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Gach Saran.—Delimitation of this field continues steadily. Two additional producers comparable in capacity to those reported last year have been completed. No forecast can be given regarding the size of this field until edge water has been struck, but the zone proved so far is approximately 20 miles along the strike and 5 miles across at its widest part. Considerable survey work is proceeding in connection with the piping of oil from this field to the coast.

Other Areas.—Exploratory drilling is being undertaken in other areas within the company's concession. At Agha Jari, which is some 55 miles southeast of Haft Kel and 70 miles northwest of Gach Saran, a deep boring has indicated the existence of productive conditions. On the Lali structure, some 20 miles northwest of Masjid-i-Sulaiman, a well has penetrated 1200 ft. of Asmari, with meager production, and further wells are being drilled but at this juncture no reliable indication of the potentialities of this structure can be given. At Pazanun, adjacent to and southeast of Agha Jari, two wells have encountered gas at considerable depth.

General.—No new developments in drilling technique can be reported. Considerable research into pressure drilling and mud flush problems has been made, and is still continuing, with the object of coping with the great depths and high pressures already encountered and anticipated in future developments.

Oil and Gas Development in Iraq during 1938

By Ben B. Cox,* Member A.I.M.E.

(New York Meeting, February, 1939)

Oil produced in Iraq for export during 1938 was 31,354,090 bbl., or a daily average of 85,901 bbl. This is an increase of 182,614 bbl., or 0.5 per cent over 1937. All oil exported was produced from the Kirkuk field.

The Khanaqin Oil Company, Ltd., a subsidiary of the Anglo-Iranian Oil Company, Ltd., continued to supply local market requirements from its Naft Khaneh field in the Transferred Territories.

Slightly more than 32,000,000 bbl. was produced in Iraq, a small part of which was used in field operations. During the year 12 wells were completed and 9 wells were drilling at the end of the year. Of the completions, 5 were producers and 1 was an oil-water level observation well in proved fields, and 6 were listed as failures.

Basrah Concession

The outstanding event of the year was the granting, by the Kingdom of Iraq, of a 75-year concession embracing approximately 89,000 sq. miles to the Basrah Petroleum Company, Ltd., a British company with French and American participation. The concession covers all parts of the Kingdom, its territorial waters, islands, submerged lands, and its interest in the Neutral Zone separating Iraq and Saudi Arabia that

Table 1.—*Oil and Gas Production in Iraq*

Line Number	Field	Age, Years to End of 1938	Total Oil Production, Bbl.[1]			
			To End of 1938	During 1937	During 1938	Daily Average during Nov. 1938
1	Kirkuk	11	126,158,192	31,171,476	31,354,090	81,496
	Qaiyarah-Najmah-Jawan-Qasab:					
2	Lower Fars zone	3	0	0	0	0
3	Continuous limestone zone	11	0	0	0	0
4	Pilsner zone	4	0	0	0	0

[1] Oil delivered to the Mediterranean pipe line converted at an average of 7.6 bbl. per ton.

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were not already under concession to the Iraq Petroleum Company, Ltd., Khanaqin Oil Company, Ltd., and British Oil Development Company, Ltd.

A geological survey of the concession was in progress at the close of the year.

B.O.D. Concession

Up to the end of 1938 no merchantable oil had been found in the British Oil Development Company's concession. Approximately 18,000 bbl. of road oil was supplied to the Iraq Government free of cost under the terms of the Convention.

Three productive wells were completed in proved fields. Exploratory drilling below the Continuous Limestone zone in proved fields, and exploratory drilling on unproved structures resulted in six failures during the year.

Mosul Oilfields, Ltd., through its operating subsidiary, the British Oil Development Company, Ltd., has drilled on 18 structures in its concession. A nonasset reserve of black oil ranging from 12.2° to 19.5° A.P.I., with a sulphur content of from 6 to 11.8 per cent, has been developed in eight structures. The production is from the Lower Fars, Continuous Limestone zone, and the Pilsner. Two structures have been tested to the Jurassic, and one structure was being tested in the Paleozoic at 9012 ft. at the end of the year. This is the deepest bore drilled in Iraq to date. Exploratory drilling was continuing with nine rigs at the end of the year.

Geological exploration continued throughout the year.

I.P.C. Concession

All drilling by the Iraq Petroleum Company, Ltd. was confined to the Kirkuk field. Two new producers and one oil-water level observa-

Table 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells					Depth, Average in Feet	Oil-production Methods at End of 1938	Character of Oil, Approx. Average during 1938				
	Completed to End of 1938	During 1938	At End of 1938			Bottoms of Productive Wells	Number of Wells	Gravity A.P.I. at 60° F.			Sulphur, Per Cent	Base[2]
		Completed	Temporarily Shut Down	Producing Oil Only	Total Producing		Flowing	Maximum	Minimum	Weighted Average		
1	38	2	21	17	17	2,194	17	36.2	35.5	36.0	1.8	M
2	2	0	2	0	0	650		18.4	18.1	18.2	6.0	M
3	43	0	43	0	0	690		19.5	12.2	15.8	6.7	M
4	7	3	7	0	0	1,500		18.4	12.6	17.0	7.0–11.8	M

[2] M, mixed.

tion well was completed during the year. The producers were drilled to better distribute the 85,000-bbl. daily offtake from the producing area. Of the 11 dry or near-dry holes listed on Table 1, 10 are oil-water level observation wells.

No test has been drilled below the Globigerina marls, which immediately underlie the Main Limestone in the East Tigris concession. To date the Iraq Petroleum Company, Ltd. has drilled nine structures in the East Tigris concession. Eight wells on four structures were abandoned above objective for mechanical reasons or because of high pressures. One test on another structure found noncommercial black oil in the Main Limestone similar to West Tigris oil. The remaining tests were suspended above objective in order to concentrate on the unitized development of the Kirkuk field.

Pressures, gas-oil ratios, and edge-water movement were satisfactory at Kirkuk. All wells were produced by flowing. Experimental acidizing was carried out on one well. To improve efficiency, a fourth unit was added to the stabilization plant, so that before the end of the year 100 per cent stabilized sweet crude was being delivered through the pipe line.

Mediterranean pipe-line deliveries continued normal at both Haifa and Tripoli, notwithstanding the political unrest in Palestine. Losses due to more than 60 instances of sabotage in the Palestine sector amounted to less than 0.4 per cent of the throughput.

Transferred Territories Concession

The Anglo Persian Oil Company, Ltd., through its subsidiary, the Khanaqin Oil Company, Ltd., continued normal exploitation of its Naft Khaneh field, refining and marketing through the Rafidain Oil Company, Ltd. for local Iraq market.

Table 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1938		Producing Rock					Number of Dry and/or Near-dry Holes to End of 1938[3]	Deepest Zone Tested to End of 1938	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[e]	Character[f]	Porosity[g]	Structure[h]		Name	Depth of Hole, Ft.
1	y	y	Main Limestone	Mio, Olig, Eoc	L	Por	Af	11	Eocene	4,213
2	y	y	Lower Fars	Mio	L	Por	A	0	Jurassic	4,790
3	y	y	Continuous Limestone	Mio, Olig, Eoc	L	Por	A	8		
4	y	y	Pilsner	Cre	L	Por	A	7		

[e] Footnotes to column heads and explanation of symbols are given on page 240.
[3] Includes oil-water level observation wells.

Petroleum Development in Mexico during 1938

By V. R. Garfias,* Member A.I.M.E.

(New York Meeting, February, 1939)

After a series of fruitless negotiations, the Mexican Government, on March 18, 1938, decreed the expropriation of several oil companies, and took possession of the properties, offices and records not only of the expropriated companies but of others not legally expropriated. This condition prevails to date.

Table 1.—*Production of Crude Oil in Mexico*
Thousands of Barrels

Field	1937	1938			Total to End of 1938
		Jan. 1 to Expropriation on March 18	March 18 to End of Year	Total	
Northern (11° to 14° A.P.I.)	9,828	1,600	4,009	5,609	739,581
Southern (20° to 24° A.P.I.)	8,294	1,450	2,814	4,264	1,022,395
Poza Rica (33° to 34° A.P.I.)	18,634	5,308	17,366	22,674	69,643
Tehuantepec (32.5 A.P.I.)	9,980	1,770	3,623	5,393	96,035
Total	46,736	10,128	27,812	37,940	1,927,654

Table 2.—*Exports of Petroleum and Its Products from Mexico*
Thousands of Barrels

Products	1937	1938		
		Jan. 1 to Expropriation on March 18	March 18 to end of Year	Total
Panuco crude (11° to 14° A.P.I.)	5,885	515	1,292	1,807
South Fields crude (20° to 24° A.P.I.)	395	0	149	149
Poza Rica crude (33° to 34° A.P.I.)	874	175	2,936	3,111
Crude gasoline	4,388	1,265	1,547	2,812
Gas oil	2,853	932	2,206	3,138
Fuel oil	4,532	630	1,237	1,867
Asphalt	3,049	691	255	946
Kerosene	688	40	36	76
Lubricants	400	27	0	27
	23,065	4,275	9,658	13,933

Manuscript received at the office of the Institute Feb. 15, 1939.
* Cities Service Company, New York, N. Y.

The expropriation of oil properties is but one incident in a governmental program which has already included other important industries and adversely affected nationals as well as foreigners.

As was to be expected, expropriation brought about drastic changes in the economic picture of the petroleum industry. The daily average crude production in 1938, which before expropriation was close to 132,000 bbl., declined approximately 27 per cent, to 96,500 bbl. daily (Table 1).

TABLE 3.—*Destination of Petroleum Exports from Mexico*
THOUSANDS OF BARRELS

Destination	1937		1938	
	Exports	Percentage of Total	Exports Since Expropriation March 18	Percentage of Total
United States	6,856	29.7	2,080	21.5
Great Britain	5,386	23.4	0	0
Netherlands West Indies	4,299	18.6	0	0
Germany	2,521	10.9	5,460	56.5
Australia	705	3.1	50	0.5
Belgium	610	2.7	585	6.1
Cuba	485	2.1	0	0
Brazil	419	1.8	10	0.1
Sweden	283	1.2	397	4.1
Chile	213	0.9	0	0
Italy	186	0.8	309	3.2
Union of South Africa	162	0.7	0	0
France	156	0.7	248	2.6
Guatemala	131	0.6	0	0
Japan	0	0	233	2.4
Others	653	2.8	286	3.0
Total	23,065	100.0	9,658	100.0

Exports in 1938 before expropriation averaged 55,520 bbl. daily and declined to 33,535 bbl., or approximately 39.5 per cent after expropriation (Table 2). The destination of the exports likewise changed (Table 3).

It should be noted that exports to Germany in 1938 since expropriation include not only the oil shipped directly from Mexico; that practically all the Mexican oil exported to the United States goes under bond to be refined there and the refined products exported, and that a large part of these refined products goes to Germany. The actual 1938 exports of Mexican oil to Germany since expropriation including those shipped directly and those shipped indirectly through the United States were closer to 70 per cent of the total exports than to the 56.5 per cent shown above.

Table 3 also shows that since expropriation exports to Italy have increased, and that Japan has become a buyer of Mexican oil. Much of the Mexican oil exported to Germany, Italy and Japan is paid for largely by exchange of manufactured goods.

Apparently to counteract the decline in exports and the depreciation of the peso, a 12 per cent ad valorem tax to be applied to exports was created on Aug. 10. The total tax per barrel on Mexican oil exported increased as much as 75 per cent after expropriation (Table 4).

TABLE 4.—*Petroleum Export Taxes, Mexico*
U. S. CENTS PER BARREL

Product	Dec. 1936	Dec. 1937	November 1938			
			Old Taxes	12 Per Cent Ad Valorem	Total	Increase over Dec. 1937, Per Cent
Panuco crude	11.7	11.2	9.0	10.7	19.7	75.9
South fields	18.8	20.4	13.9	10.7	24.6	20.6
Poza Rica crude			13.9	10.7	24.6	
Crude gasoline	25.2	25.7	20.9	19.3	40.2	56.4
Fuel oil	16.8	18.4	12.5		12.5	R 32.1
Asphalt			2.5		2.5	
Crude kerosene	15.2	19.0	14.9	18.0	32.9	73.2

With the exception of some 300,000 bbl. of Panuco crude that were purchased before expropriation, practically all the oil exported after expropriation has been paid for largely in barter. Although no direct comparison can be made of prices before and after expropriation, it is evident that expropriation has brought about a demoralization of the entire price structure. To illustrate: At the beginning of the year Panuco crude was selling f.o.b. Tampico at 91 to 96 U. S. cents per barrel, excluding taxes, while after expropriation this crude could have been purchased for approximately 45 U. S. cents per barrel. After expropriation Poza Rica crude was sold f.o.b. Tampico for about 72 U. S. cents a barrel exclusive of taxes (97¢ including all taxes), but payment was made largely on a barter basis. Later in the year, Panuco sold, f.o.b. Tampico, for about 65¢ exclusive of taxes (85¢ including taxes) and Poza Rica for about 60¢ f.o.b. Tampico exclusive taxes of (85¢ including taxes), both sales largely on a barter basis.

Oil and Gas Production in the Netherlands East Indies, Sarawak and Brunei

Line Number		Age, Years to End of 1938	Total Oil Production, Bbl. To End of 1938	Total Oil Production, Bbl. During 1937	Total Oil Production, Bbl. During 1938	Daily Average during December 1938	Average Oil Production, Bbl. per Well Daily during December 1938	Total Gas Production, Millions Cu. Ft. During 1937	Total Gas Production, Millions Cu. Ft. During 1938
1	Sarawak + Brunei	29	84,910,025	5,733,000	6,367,200	18,378	41	3,423	3,411
2	Balikpapan + Tarakan	43	355,766,660	12,309,000	12,180,000	34,161	44	10,903	11,302
3	Ceram	42	6,091,705	497,000	563,000	1,387	29	26	22
4	Tjepoe	51	93,095,286	7,198,446	6,969,103	16,968x	38x	4,526x	4,497x
5	Pladjoe	42	261,481,872	28,118,053	28,652,568	41,677x	71x	12,526x	15,369x
6	P. Brandan	53	127,050,895	6,777,000	7,509,000	24,000	162	7,617	7,867
	Total		928,396,443	60,632,499	62,240,871	136,571x	56x	39,021x	42,468x

1 cu. m. = 35.31 cu. ft.

Line Number	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Temporarily Shut Down	At End of 1938: Producing Oil Only	At End of 1938: Producing Gas Only	At End of 1938: Total Producing	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Oil Production Methods at End of 1938, Number of Wells: Flowing	Pumping	Gas or Air Lift	Not Classified
1	590	24	4	44	447	4	495	340–5,790	130–5,564	18	394	35	
2	1,447y	86	15		783	3	786	230–3,280	210–3,210	28	735	20	
3	84	4			48	2	50	260–1,020	240–1,000		48		
4	3,896y	207	11	130	1,483	2	1,485	160–2,950	130–2,880	36	398	8	456
5								290–6,300	160–6,200	150	112	323	
6	781	34	4	18	148		166	300–4,140	260–4,100	77	30	41	
	6,804y	258	34	192	2,909	11	3,112			309	1,717	427	456

Line Number	Producing Formation: Name	Age[e]	Character[f]	Porosity, Per Cent[g]	Structures[h]	Number of Dry and/or Near-dry Holes to End of 1938	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
1	Seria and Miri	Mio	Ssh	18	Af	87	Miri deep shale	6,180
2	Balikpapan-Poeloe Balang and Tarakan	Pli + Mio	SsH, S	10–30	Af	231y	Poeloe Balang	5,900
3	Boela formation + Triassic	Pli + Tri	SsH		Af	41	Triassic	2,400
4	Mergelklei—Globigerinae—Orbitoid zones	Pli + Mio	S, SH, LS	15–35	Af	391y	Basismergel	10,000
5	Palembang and Telissa zones	Pli + Mio + Paleogene	S, SH, SS	13–28	Af	376y	Under Telissa	8,800
6	Seuroela-Keutapang-Grensklei zones	Pli + Mio	S, SH, SS	15–35	Af	253y	Grensklei	7,700

[a] Footnotes to column heads and explanation of symbols are given on page 240

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Petroleum Developments in Peru during 1938

By Oliver B. Hopkins,* Member A.I.M.E.

(New York Meeting, February, 1939)

Peru produced approximately 15,838,610 bbl. of oil during 1938, which was 1,618,406 bbl. below its production during 1937. As in recent years, the entire output of the country came from the La Brea-Parinas, Lobitos-Restin, and Zorritos fields, which are all situated along the northwestern coast.

Outside of the proven areas, the drilling of test wells was continued by the Peruvian Government on the reserved zone near Zorritos. Six wells have been completed or are drilling. Of these one is a gas well at 2619 ft. and one is dry at 1415 ft. It is reported that three standard and two rotary rigs are being used. In southern Peru, in the Pirin region north of Lake Titicaca, the Government made a geological study of the National Reserve. In eastern Peru, the Cia. Petrolera El Ganso Azul continued its activities in the montana region, where its first well was reported to have had a show of oil at 1000 feet.

There was also renewal of leasing activity in eastern Peru, where approximately 380,000 acres of new leases were filed on near Contamana.

La Brea-Parinas Estate.—Production of crude oil on this property of International Petroleum Co. Ltd. amounted to 13,137,988 bbl. which was

Table 1.—*Oil and Gas Production in Peru*

Line Number	Field, *Department*	Age, Years to End of 1938	Total Oil Production, Bbl.			
			To End of 1938	During 1937	During 1938	Daily Average during Nov. 1938
1	La Brea-Parinas, *Piura*	49	191,528,755	14,722,754	13,137,988	36,556
2	Lobitos and Restin, *Piura*	34	43,977,405	2,695,048	2,660,622	6,960
3	Zorritos, *Tumbes*	55	3,183,362	39,214	40,000	110
4	Pirin (Huacane), *Puno*	*x*	0	0	0	0
	Total		238,689,522	17,457,016	15,838,610	

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a decrease of 1,584,766 bbl. from its 1937 figures. The total production from 1890 to Dec. 31, 1938, was 191,528,755 bbl. During 1938 a total of 176,186 ft. was drilled; 162,823 ft. in new wells and 13,363 ft. in deepening existing wells. In all, 65 wells were completed, 54 of which were classed as producers, 2 as gas wells and 9 as dry holes.

Thirty-one wells were cleaned out or deepened during the year. The average depth attained by new wells completed during 1938 was 2476 ft., compared with 2367 ft. for the new wells completed during 1937. The use of rotary tools continued to increase and this method now predominates, especially for deeper drilling or where high pressures are expected. Of the wells completed in the year, 34 were drilled by rotary, 11 by standard and 20 by star rigs.

Drilling operations during the year included the drilling of several semi-exploratory wells, which proved normal additions to known productive areas. Deepening of older wells yielded encouraging results, especially in the prolific Section 16 area.

Experimental work on water-flooding by injection into downdip wells gave promise of favorable results in at least one of three areas under test.

Lobitos Property.—The Lobitos property, north of the La Brea-Parinas estate, produced approximately 2,660,622 bbl. during 1938, a decrease of 34,426 bbl. from 1937. Total production to the end of 1938 amounted to 43,977,405 bbl. It is reported that the well potentials at a new shallow productive area found by this company east of El Alto are rather small. The company has a natural gasoline plant, but no refinery of its own in Peru. Most of its production is exported to its refinery at Ellesmere Port, England, to Argentina and to other points.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells								Oil-production Methods at End of 1938						Character of Oil, Approx. Average during 1938	
	Completed to End of 1938	During 1938		At End of 1938					Number of Wells					Injection into Reservoir	Gravity A.P.I. at 60° F.	
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas	Producing Gas Only	Total Producing	Flowing	Pumping	Gas Lift	Air Lift	Miscellaneous		Maximum	Minimum
1	3,038	65	9	83	y	1,842	19	1,944	92	1,741	9	0	67	34	H.C.T. 39.4 L.C.T. 34.1	38.6 33.0
2	1,014	32	0	y	y	y	y	741	y	y	y	y	y	y	y	y
3	y	y	y	y	y	y	y	42[1]	y	y	y	y	y	y	y	y
4	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y

[1] End of 1937.

Zorritos Property.—The production from the Zorritos property is estimated to have amounted to approximately 40,000 bbl. during the year 1938.

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1938: Gravity A.P.I. at 60° F., Weighted Average	Sulphur, Per Cent	Base[2]	Producing Rock: Name	Age[e]	Character[f]	Structure[g]	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
1	38.9 33.6	y	M	Verdun, Lomitos, Parinas Negritos, Salina	Eoc	S	AF	Eocene	
2	y	y	y	Terebratula, Lower Caverno	Eoc	S	AF	Probably Cretaceous	y
3	y	y	y	Zorritos	Mio	S	MF?	y	2,900?
4	y	y	y	y	y	y	y	y	y

[e] Footnotes to column heads and explanation of symbols are given on page 240.
[2] M, mixed.

Oil and Gas Production in Poland in 1938

By Josef Zwierzycki*

By an extension of drilling activities in 1938, the Polish oil industry succeeded not only in maintaining production but even in increasing it slightly. This increase, however, was from present oil reserves and not due to the discovery of any new fields.

Most of the new wells were drilled in the Jaslo district, particularly in the Lipinki-Libusza[1] oil field, because of the shallow depth of the producing sands. At the Boryslaw field the 12,332 meters drilled could not compensate for the steady drop in production. A drilling campaign similar to that of the previous year in the Stanislawow district resulted in a slight decline of production.

A number of the new wells have been subsidized by the Fund for the Advancement of Drilling[2] in Poland. As the present sums at the disposal of this fund are insufficient for a great exploration program, they are chiefly used for the maintenance of the actual production. New wells on known folds, but more than 1000 m. outside the present productive areas, are entitled to a subsidy. Applications for wildcats outside the known productive areas have not been received in 1938. Even when the Polish oil industry was prosperous, wildcatting was not frequent and in their present impoverished condition the oil companies are no longer able to bear such financial burdens. The only way to start a large-scale drilling campaign on the still existing promising areas seems to depend on the granting of new substantial subsidies from the Treasury. Such measures are being considered by the Polish Government.

It has been suggested that a fund for wildcatting might be raised by a small increase in the price of benzine. An advance of one grosz per liter of benzine would raise, on present home consumption of 108,000 kilogram-tons, about 1.3 million zloty, an advance of 5 grosze more than 6 million zloty.[3] This small increase in price would hardly be felt by the motor-car owners, as it would mean an extra expense of 80 to 400 zloty in a year.

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[1] The oil fields are indicated in this paper by one or two characteristic village names. The cumbersome enumeration of a great number of rural parishes does not make the position or the extension of Polish oil fields clearer to foreign readers.

[2] *Trans.* A.I.M.E. (1936) **118,** 491.

[3] 0.24 and 1.13 million dollars.

TABLE 1.—*Oil and Gas Production in Poland*

Line Number	Field, *Province*	Age, Years to End of 1938	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil	Gas[a]	Total	To End of 1938	During 1937	During 1938	Daily Average during Nov. 1938
1	Lipinki-Libusza, etc., *Gorlice*	73	1,075		1,075	5,021,864	277,970	401,870	1,103
2	Biecz-Korczyna, *Gorlice*	41	65		65	402,860	28,210	26,250	71
3	Sekowa-Siary etc. } Magura-upthrust { *Gorlice*	66	100		100	757,255	20,720	15,260	42
4	Ropianka } Magura-upthrust { *Krosno*	70	30		30		1,750	1,540	4
5	Harklowa, *Jaslo*	68	130		130	1,747,242	52,430	53,970	147
6	Roztoki-Sadkowa, etc. } Potok-anticline { *Jaslo*	29				226,424	35,580	14,280	38
7	Mencinka-Jaszczew } Potok-anticline { *Jaslo*	29	1,335	515	1,850	260,348	27,580	44,660	122
8	Potok-Toroszowka } Potok-anticline { *Krosno*	47				5,568,088	98,210	130,060	356
9	Krosno-Kroscienko } Potok-anticline { *Krosno*	50				1,973,372	30,100	25,480	70
10	Klimkowka, *Krosno*	48	30		30		13,346	2,660	7
11	Bobrka-Rogi, etc., *Krosno*	80	225		225	5,530,436	51,450	47,600	130
12	Lubatowka-Wulka, etc., *Krosno*	50	275		275		15,813	30,240	82
13	Strachocina-Gorki } Zmiennica-Strachocina-anticline { *Sanok*	10		494?	494?			630	1.4
14	Zmiennica-Turzepole } Zmiennica-Strachocina-anticline { *Brzozow*	42	67		67	704,510	15,260	25,690	70
15	Humniska-Grabounica, etc., *Krosno*	42	321		321		80,990	79,520	217
16	Weglowka, *Krosno*	51	148		148	2,024,735	26,320	24,150	64
17	Tyrawa Solna, etc., *Sanok*	26	50		50		12,650	30,800	84
18	Total Jaslo district		3,851	1,009	4,860	26,272,948	823,867	954,660	2,608
19	Lipie-Czarna, etc., *Lesko*	52	100		100		19,810	36,569	100
20	Wankowa-Paszowa, etc., *Lesko*	52	568		568	2,329,953	161,630	165,953	458
21	Strzelbice, *Sambor*	57	62		62	619,828	18,648	15,350	41
22	Boryslaw, *Drhobycz*	44	3,700		3,700	181,408,383	1,820,000	1,732,609	4,747
23	Opaka, *Drohobycz*	42	25		25	139,135	2,659	3,386	9
24	Schodnica-Urycz, *Drohobycz*	66	1,110		1,110	20,237,919	338,030	333,016	923
25	Daszawa, *Drohobycz*	17		1,500	1,500				
26	Total Drohobycz district		5,565	1,500	7,065	210,446,559	2,359,987	2,286,883	6,278
27	Rypne-Perehinsko, *Dolina*	51	1,500		1,500	2,370,205	101,290	97,685	270
28	Majdan-Kosmacz, *Kolomyja*	49	260		260	244,612	22,848	33,475	85
29	Bitkow, *Nadworna*	39	1,080	100	1,180	6,372,084	149,800	149,010	412
30	Pasieczna, *Nadworna*	58	400	150	550		30,000	25,274	70
31	Sloboda Rungurska, *Nadworna*	63	120		120		10,640	10,824	38
32	Kalusz, *Kalusz*	3		?	?				
33	Total Stanislawow district		3,360	250	3,610		325,270	316,268	875
34	Total Poland		12,776	2,759	15,535	248,034,150	3,509,124	3,557,811	

[a] Footnotes to column heads and explanation of symbols are given on page 240.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.: To End of 1938	During 1937	During 1938	Maximum Daily during 1938	Number of Oil and/or Gas Wells: Completed to End of 1938	During 1938: Completed	During 1938: Abandoned	At End of 1938: Temporarily Shut Down	Producing Oil[b]	Producing Gas[c]	Total Producing	Oil-production Methods at End of 1938, Number of Wells: Flowing	Pumping	Gas Lift	Swabbing	Pressure, Atm. Kg. per Sq. Cm.: Initial	Average at End of 1938: 1937	1938
1		61.5	100.4	0.32	1,036	122	12	15	644	1	645		577		67		2–25	
2		65.0	56.9	0.15	58	5			45		45		45					
3		3.3	3.6		185	11	1	22	107	2	109		84		23			
4		26.0	23.7	0.07	37			7	16		16		12		4			
5		39.0	33.7	0.09	277	4	1	7	143	1	144		138		5			
6	58,213 (lines 6–7)	3,492	4,413	17.5	39	3		1	4	17	21				4	114	91	85
7		406	916	3.7	22	3	1	2	19	14	33	1		6	12	110	16	10
8		140	157	0.5	267	12		9	96	3	99	3	93			35		5–10
9		10.7	12	0.04	111	2		1	45		45		44		1			
10		22.0			65	10		2	28		28		23		5			
11		123.0	111.3	0.26	253	3	1	9	91	3	94		65		26	60		
12		21.0	70.7	0.3	91	6	1	11	77		77		53		24			
13	1,197	162.0	255	0.74	3					3	3					95	56	?
14		32.0	41	0.09	62	5	2		41		41		35		6			
15		262.0	192	0.6	116	5		7	58		58		28	5	25	50	5	5
16		27.0	28.5	0.08	227	2		5	86		86		85		1			
17			4.1		40	11	2	3	47		47		36		11			
18	64,605	4,892.5	6,418.9		2,889	204			1,547	44	1,591	4	1,318	11	214			
19		3.5	8.6		78	7		5	30	1	31		30					
20		45.0	54.8		455	10	5	8	376	1	377		370		6			
21		9.0	8.8		74	1		1	38		38		38					
22	196,333	4,367.0	3,555.6	10.0	1,303	8		187	598	110	708		72		526			
23					15			2	5		5		5					
24		243.0	333.6		822	16			572		572		572					
25	54,738	5,731.0	6,646.0	18.0	32	8		7		25	25					63	45–39	45–36
26	251,071	10,398.5	10,607.4		2,779	50			1,619	137	1,756		1,087		532			
27		523.0	514.0	1.4	240	7		19	136		136		95		41			
28					119	6		14	108		108	2	72		34			
29		1,327.0	1,606.0	4.5	188	4		8	104	9	113	3	5		96			
30		95.0	88.0	0.2	196	1			36		36		11		25			
31					300				52		52		52					
32		350.0	510.0	1.4	3			1		2	2						40?	
33	38,031	2,295.0	2,718.0	7.5	1,046	18			436	11	447	5	235		196			
34	353,707	18,567.5	19,744.3		6,714	272			3,602	292	3,794	9	2,640	11	942			

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1938: Gravity A.P.I. at 60° F., Maximum	Gravity A.P.I. at 60° F., Minimum	Gravity A.P.I. at 60° F., Weighted Average	Paraffin Per Cent	Base[1]	Character of Gas, Approx. Average during 1938: B.t.u. per Cu. Ft.	Gasoline, Grams per C.C.	Producing Formation: Name	Age[e]	Depth, Average in Feet: Bottoms of Productive Wells	Depth, Average in Feet: To Top of Productive Zone	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]
1	32	38	34	3.0–7.4	P	1,124		Ciezkowice I, IIa. Cre	Eoc, Cre	150–2,700		S	18.7–27.3	80	AM
2	38	43	39	0.3–1.1	A	1,124		Ciezkowice I, II	Eoc	480–1,440		S		120	diapir
3	29	40	35	0.4	A			Magura facies	Cre	450–1,350		S		40	A
4	29	31	31	0.4	A			Magura facies	Cre	380–1,120		S		60	A
5	21	27	27	0.8	A			Krosno beds	Olig	1,066		S		150	overthr.
6	40	42	40	0.4	A	1,011	10–45	Ciezkowice II, III	Eoc, Cre	3,000–3,900	3,000–3,900	S	12.2	245	A
7	42		42	4.0	P		25–50	Ciezkowice II, III	Eoc, Cre	2,400–3,600	2,700	S		198	diap.
8	39	51	42	0.4	A	1,124	150	Ciezkowice II, III	Eoc, Cre	416–1,120		S		80	diap.
9	29	34	32	0.7–8.0	M		150	Ciezkowice I, II	Eoc	900–2,000	1,600	S		190	diap.
10			35		A			Krosno beds	Olig	360–1,120		S		132	Af
11	32	38	34	0.5–6.2	AP		225	Ciezkowice I–III, IV	Eoc, Cre	480–3,200		S		160	A
12			29	0.3	A		150	Ciezkowice I–III	Eoc, Cre	690–2,120		S		100	A
13						1,124	13	Czarnorzeki	Cre	3,000	2,940	S			A
14			33	6.7	P			Ciezkowice I	Eoc	1,480–2,400		S		100	A
15	14	37	47	0.2–5.9	AP	1,067	150	Ciezkowice I, II, III	Eoc, Cre	2,300–2,940		S	19.6, 18.4, 20.5	200	diap.
16	27	30	29	0.4	A			Czarnorzeki	Cre	270–1,050		S		100	AM
17	35	45	44	0.3	A			Lower Krosno beds	Olig	300–900		S		?	Af
18															
19	38	45	42	5.1–0.1	PA			Lower Krosno beds	Olig	1,020–1,310		S		?	Af
20	30	39	34	0.5–5.9	P			Low. Krosno b.a. Menilites	Olig	1,150–1,900		S		40–50	diap.
21	21	33	32	6.2	P			Jamna beds	Cre	660		S		45	A
22	31	36	33	6.0–9.4	P	1,461	234	Boryslaw sandstone 4 hor. Eoc. 5 hor. Olig 2 hor.	Olig, Eoc Cre	4,270–5,700		S	10.0, 15.0, 17.4	30–120	overthr.
23	42	44	43	6.1	P			Lower Eocene beds	Eoc	1,970		S		50	A
24	29	39	36	0.3–5.9	AP			Jamna beds	Cre	1,480		S		150	A
25								Gas beds (Tortonian)	Mio	2,300		S	25.0	100	A
26															
27	33	39	36	4.0–8.0	P			Kliwa beds	Olig	2,625		S		60	Af
28	32	29	30	0.8–1.1	A			Eocene beds, Inoceramus beds	Eoc, Cre	1,150–1,920		S		40–80	Af
29	34	48	44	1.1–8.4	P			Kliwa beds	Olig	3,610		S		15–30	Af
30	38	56	45	0.2–4.9	AP	1,067		Kliwa beds a. platy beds	Olig, Cre	660–4,700		S		15–30	Af
31	35	37	36	5.2–5.9	P			Jamna beds	Cre	185–2,400		S		80	Af
32								Gas beds (Tortonian)	Mio			S		?	?
33															
34															

[1] P, paraffin, A, asphalt; M, mixed.

The next step in the intensifying of oil production in Poland will be the introduction of more efficient methods of exploitation, such as repressuring (Marietta method), flooding and perhaps mining. Repressuring was successfully applied in the Potok field in 1930–1934, but, owing to the division of the productive area into a large number of lots owned by disagreeing operators, the method had to be discontinued. At the Schodnica field repressuring has been used since May 1930 on a 100-acre area belonging to the "Gazy ziemne" Company. Until August 1936 the medium was air, from that time until February of 1938 motor exhaust gases were used, but since the completion of a pipe line from the gas field of Daszawa in February 1938 natural gas only has been used. There are 10 intake wells as against 45 producers. The results have been very satisfactory; the present production of oil is about 25 per cent higher than in 1930. The production of gasoline also is higher, as the dry gases of Daszawa absorb additional fluid when passing through the oil sands.

TABLE 2.—*Drilling Statistics, Poland*
METERS

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawow	Total
1938	77,901	35,306	12,332	25,952	151,491
1937	66,908	33,947	14,269	24,123	139,247
1936	48,166	30,307	9,154	19,374	107,001
1935	39,449	22,981	10,981	12,661	86,122
1934	37,703	21,569	8,020	10,641	77,933

TABLE 3.—*Number of Producing Wells*

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawow	Total
1938	1,591	1,048	708	447	3,794
1937	1,423	1,014	717	428	3,582
1936	1,291	1,002	669	396	3,358
1935	1,149	1,025	650	253	3,208
1934	1,195	1,046	632	248	3,121

TABLE 4.—*Total Oil Production, Poland*
TANK CARS OF 10,000 KILOGRAMS (10 KILOGRAM-TONS)

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawow	Total
1938	13,638	7,918	24,751	4,518	50,825
1937	11,769	7,828	25,886	4,647	50,130
1936	10,789	7,901	27,132	5,241	51,068
1935	9,908	9,429	28,598	3,541	51,476
1934	9,538	9,753	30,138	3,491	52,920

A repressuring scheme has been worked out in detail for the Boryslaw field and a project for the Lipinki field is in preparation, but cooperation among the numerous producers does not seem to be possible except by legislative enactment. The major producers are planning to ask the assistance of the Polish Government.

As for the problem of salt dome production in northwestern Poland, the first steps of realization have been undertaken. In the province of Pomorze, three salt domes (Inowroclaw, Wapno and Gora) have been known since the end of the last century. In the salt mine of Inowroclaw traces of oil have been observed repeatedly. In the course of the recent geophysical survey an indication of a fourth dome near the township

TABLE 5.—*Total Gas Production, Poland*

THOUSANDS OF CUBIC METERS

Year	Jaslo	Outside Boryslaw	Boryslaw Fields	Stanislawow	Total
1938	183,601	211,661	100,721	77,077	573,068
1937	152,486	187,657	124,258	66,096	530,497
1936	131,437	165,258	129,048	57,560	483,303
1935	136,476	168,507	137,390	43,036	485,409
1934	121,083	149,722	154,516	43,633	468,954

TABLE 6.—*Gasoline Production, Poland*

KILOGRAMS[a]

Year	Jaslo	Drohobycz	Stanislawow	Total	Number of Gasoline Plants			
					Jaslo	Drohob.	Stanis.	Total
1938	3,974,315	34,648,182	4,333,576	42,956,073	7	15	6	28
1937	3,586,339	32,786,218	4,410,952	40,783,509	7	15	6	28
1936	3,476,616	31,833,221	4,571,970	39,881,807	6	13	5	24
1935	3,831,056	32,887,608	2,763,744	39,482,408	6	14	5	25
1934	4,436,585	33,349,333	2,952,171	40,738,069	7	16	4	27

[a] One kilogram = 2.205 pounds.

TABLE 7.—*Ozokerite Production, Poland*

KILOGRAMS

Year	Boryslaw	Stanislawow (Dzwiniacz-Starunia)	Total
1938	335,091	148,560	483,651
1937	322,530	165,914	488,444
1936	343,593	99,299	442,892
1935	300,945	69,963	370,908
1934	89,138	67,027	156,165

of Barcin has been found. An exploration well started by the Geological Survey of Poland has reached a depth of 540 m. in tilted, gypsiferous Triassic. The geophysical survey is to be continued with Thyssen gravimeters and refraction and reflection seismographs.

From the discovery of a salt dome to the creation of an oil industry in northwestern Poland, however, is a long way. After the stimulating work of the Geological Survey, capital must be interested. By an amendment of the mining law and the grant of drilling subsidies, Germany has been able to create in similar conditions practically a new oil industry in the past few years. Poland will have to follow that example. The matter is widely discussed in the Polish daily press and the technical periodicals, but a legislative project has not yet been introduced to Parliament.

Gas production is developing steadily in Poland. The Daszawa field has been recently delimited in the southeastern sector, where edge water has been reached. The structure is a very slightly raised dome. According to the current geological opinion, a row of such domes occurs in the Miocene geosyncline bordering the Carpathian Mountains along a line, where the upthrusts and complicated folds on the mountain-side end and the gentle structures of the foreland begin.

On this tectonic line are situated the gas fields of Opary, Daszawa, Balicze, Kalusz and Kossow. On the same line a new gas field, Popowice, near Przemysl, was discovered by the Pionier Company at the close of 1938. The first gas sand occurs at a depth of 500 m. As this well has been started with a heavy rotary outfit, the drilling will be continued for the exploration of a possible oil field below.

All the above mentioned areas except the Carpathian Mountains produce generally dry gas.

Within the Carpathians only more or less wet gases are found. The previous waste of gas on the Polish oil fields belongs to history. At the present time every cubic meter of it is carefully gathered and stripped of gasoline. So are the gases of the Roztoki-Sadkowa and Strachocina-Gorki gas fields. The production of gasoline is developing favorably in Poland, in spite of the declining yield of crude.

Oil and Gas in Rumania

(New York Meeting, February, 1939)

THE 1938 production for all of Rumania amounted to 48,984,200 bbl., as compared with 53,239,500 bbl. in 1937, which represents a drop of 4,255,300 bbl., or 8 per cent. Of the various fields, there are only two major increases in production—Baicoi-Tintea with 3,092,400 bbl. and

TABLE 1.—*Oil and Gas Production in Rumania*[1]

Line Number	Field, *Department*	Age, Years to End of 1938	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil	Gas	Total	To End of 1938	During 1937	During 1938	Daily Average during Nov. 1938
1	Glodeni, *Dambovita*	41	400		400	559,500	10,000	9,500	25
2	Doicesti, Sotanga, *Dambovita*	26	200		200	22,600			
3	Malul Rosu, *Dambovita*	35	200		200	5,800			
4	Colibasi, Resca, *Dambovita*	82	1,470		1,470	3,243,300			
5	Draganeasa, *Prahova*	58	200		200	343,900			
6	Campina, *Prahova*	54	580		580	33,083,700	235,200	225,000	570
7	Bustenari, Runcu, *Prahova*	94	5,250		5,250	104,923,000	1,775,400	1,600,000	4,750
8	Scaiosi, *Prahova*	9	550		550	72,000	5,600	20,200	30
9	Copaceni, *Prahova*	34	250		250	1,793,700	103,000	90,000	225
10	Filipesti Padure, *Prahova*	28	250		250	2,030,300			
11	Pacureti, *Prahova*	39	150		150	230,500	700		
12	Matita, *Prahova*	39	200		200	80,300			
13	West Gura Ocnitei, *Dambovita*	9	7,550		7,550	66,372,100	4,825,400	4,150,000	14,200
14	Gorgota, Ochiuri, *Dambovita*	25	1,300		1,300	41,130,900	2,534,100	2,700,000	6,800
15	Moreni, *Dambovita, Prahova*	35	3,700		3,700	322,717,800	17,189,400	15,230,000	41,700
16	Moreni North, *Dambovita, Prahova*	35	1,100		1,100	25,483,300	448,600	288,500	1,300
17	Piscuri, *Prahova*	11	450		450	20,501,000	2,707,700	2,500,000	6,000
18	Ditesti, *Prahova*	5	540		540	1,341,100	535,400	86,000	
19	Calinesti, *Prahova*	4	75		75	23,200	12,900		
20	Baicoi, Liliesti, Tintea, *Prahova*	77	850		850	38,940,000	1,747,600	4,840,000	15,500
21	Bucsani, *Dambovita*	5	3,900		3,900	31,525,600	7,310,000	2,760,000	7,500
22	Margineni, *Prahova*	3	450		450	634,200	291,500	210,000	500
23	Aricesti, *Prahova*	17	1,000		1,000	7,560,100	398,600	272,000	800
24	Boldesti, *Prahova*	16	5,000		5,000	72,765,300	9,950,500	8,370,000	19,100
25	Ceptura, *Prahova*	25	2,100		2,100	35,388,500	2,461,300	4,980,000	14,700
26	Orlea, *Prahova*	6	200		200	11,200			
27	Podenii Noi, Apostolache, *Prahova*	36	100		100	151,100			
28	Udresti, *Prahova*	14	100		100	138,800			
29	Sarata Monteorul, *Buzau*	69	260		260	3,656,700	54,200	46,000	140
30	Arbanasi, *Buzau*	69	400		400	15,653,900	284,900	272,000	750
31	Solont, Stanesti, *Bacau*	78	250		250	4,665,700	96,600	93,000	275
32	Zemes, Taslau, *Bacau*	78	170		170	4,762,800	146,200	140,000	415
33	Moinesti, Lucacesti, *Bacau*	78	275		275	2,795,700	97,300	92,000	265
34	Comanesti, Grozesti, *Bacau*	78	100		100	14,400	3,500		
35	Tetcani, Casin, *Bacau*	78	300		300	962,300	13,900	10,000	40
36	13 Fields, *Transylvania*	31		1,000	1,000				
37	Total		39,870	1,000	40,870	843,584,300	53,239,500	48,984,200	135,585

[1] Month of December estimates.

Manuscript received at the office of the Institute Feb. 3, 1939. Information available through the courtesy of W. P. Haynes, Member A.I.M.E.

Ceptura with 2,518,700 bbl. The greatest decrease among the major fields occurred in Bucsani, Boldesti, and Moreni. Ceptura, which showed an increase over the previous year, is expected to show a marked decrease in 1939. Baicoi-Tintea, however, will continue to expand. Although the over-all decrease in Rumanian production was only 8 per cent, this decrease would have been considerably greater without the increase in the Ceptura and Tintea fields. By excluding the gains of these two fields, the drop in Rumanian production would be 18.5 per cent under that of 1937.

In 1938, drilling amounted to 961,000 ft., as compared with 1,278,000 ft. in 1937, representing a decrease of 25 per cent.

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells						Depth, Average in Feet		Oil-production Methods at End of 1938			
						During 1938	At End of 1938						Number of Wells			
	To End of 1938	During 1937	During 1938	Maximum Daily during 1938	Completed to End of 1938	Completed	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Producing Wells	To Top of Productive Zone	Flowing	Pumping	Gas Lift	Miscellaneous
1					6						2,000	1,000				
2					4						1,900	1,700				
3					10						1,000	500				
4					30						1,400	600				
5					38	1	1				4,200	1,100				
6					281	1		66	2	68	1,200	700	1	25		42
7					1,641	11	50	540	1	541	2,500	100	1	286		254
8					9	3	2	3		3	1,800	1,450	2			1
9					19	3	2	7		7	2,200	700	1	6		
10			[2]		57						3,800	3,250				
11					14		1				4,000	2,000				
12					10						1,300					
13					322	2	20	138	3	141	5,900	5,400	7	70	17	47
14					283	20	12	77	3	80	4,000	1,300	14	41	8	17
15					1,211	27	30	493	8	501	5,600	1,400	21	324	128	28
16					388	8	10	28	1	29	4,000	1,000	2	10	4	13
17					140	15	35	85	2	87	4,000	1,200	15	54	7	11
18					9		6				7,300	6,900				
19					4		3				5,700	5,300				
20					484	39	26	99		99	8,800	600	31	37	1	30
21					145		30	84	1	85	7,300	6,500	8	54	23	
22					16		3	5	1	6	7,500	6,100	4		2	
23	1,343	From Dacid. Pli, now abandoned			59	1	11	10	4	14	7,400	5,500	5	1	7	1
24	1,428	From Dacic. Pli, now abandoned			163	16	28	105	2	107	7,900	6,900	31	7	68	1
25					224	28	51	106		106	4,100	2,400	33	60	13	
26					7		1				8,400	7,600				
27					19	1					1,700	800				
28					2		2				2,400	2,200				
29					40			4		4	1,000	200				4
30					140			69		69	1,000	200		61		8
31					192	2		84		84	2,000	1,000		78		6
32					60			37		37	1,000	200		33		4
33					40			14		14	1,000	200		14		
34					20						2,200	600				
35					66	1		10		10	1,500	500				10
36	150,000	8,300	8,000	22	70				25	25	1,500	600	25			
37					6,223	179	324	2,065	53	2,118			201	1,162	278	477

[2] 1/30 gal. gasoline per M cu. ft. gas.

Of the 35 Rumanian fields or areas, the most important, with the exception of Bucsani, remain the same as those of last year. The fields

that during 1938 made over 4,000,000 bbl. are West Gura Ocnitei, Moreni, Baicoi-Tintea, Boldesti and Ceptura. Ceptura began to come into prominence during 1937, owing to drilling on the north flank, but at the present the most favorable areas have been drilled up and the field consequently will begin to decline. At Tintea, the Meotic development is still extending the productive area, and it is expected that the field will assume an even more important position during 1939. With the exception of Tintea, extensions in other fields contributed a negligible amount to the country's production.

No additional development was carried out in the Transylvanian gas fields. A further test at Manesti on the north flank proved salt water.

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[d]			Character of Oil, Approx. Average during 1938				Producing Formation						Number of Dry and/or Near-dry Holes to End of 1938	Deepest Zone Tested to End of 1938	
		Average at End of		Gravity A.P.I. at 60° F.												
	Initial	1937	1938	Maximum	Minimum	Weighted Average	Base[3]	Name	Age[e]	Character[f]	Porosity[g]	Net Thickness, Average in Feet	Structure[h]		Name	Depth of Hole, Ft.
1	300					39	P	Meotic	Pli	S, Ss	10	40	Af	5	Helvetian	2,800
2	1,300					39	P	Meotic	Pli	S, Ss	10	50	Af	3	Helvetian	5,100
3							P	Sarmatian	Mio	S, Ss			Af	10	Sarmatian	1,000
4							P	Meotic	Pli	S, Ss	12		Af		Meotic	2,000
5			1,500				P	Meotic, Helvetian	Pli, Mio	S, Ss	12	120	MF	22	Helvetian	4,200
6	750		120			41	P	Meotic	Pli	S, Ss	15	140	MF	15	Helvetian	2,200
7	1,000		450	38	45	42	P	Meotic, Oligocene	Pli, Paleog	S, Ss	16	160	MF	100	Oligocene	7,800
8	280	100	200			40	P	Meotic	Pli	S, Ss	7	50	AF	4	Sarmatian	3,200
9	360	160	320			41	P	Meotic	Pli	S, Ss	12	50	AF	3	Meotic	3,000
10	600					43	P	Meotic	Pli	S, Ss	10	40	A	28	Sarmatian	6,400
11	1,500			26	68	52	M	Dacic, Pontic, Meotic	Pli	S, Ss	15	180	Af	10	Meotic	4,000
12							P	Meotic	Pli	S, Ss	10	10	Af		Meotic	1,300
13	1,600	70	65			33	P	Meotic	Pli	S, Ss	15	110	SA		Helvetian	6,500
14	2,000	300	300			33	M	Dacic, Meotic	Pli	S, Ss	15	150	SA	47	Helvetian	5,100
15	3,000	200	180	21	35	33	M	Dacic, Meotic	Pli	S, Ss	15	300	SA	122	Helvetian	5,700
16	2,000	1,100	600	28	39	33	M	Dacic, Meotic	Pli	S, Ss	15	90	SA	82	Helvetian	7,000
17	1,500	450	450	26	40	33	M	Dacic, Meotic	Pli	S, Ss	15	80	SA	13	Helvetian	4,000
18	700	600				33	P	Meotic	Pli	S, Ss	12	50	SA	2	Helvetian	7,300
19	1,600	1,200				33	P	Meotic	Pli	S, Ss	10	40	SA	1	Helvetian	5,700
20	2,000	450	1,500	26	45	39	M	Dacic, Meotic	Pli	S, Ss	17	200	SA	155	Meotic	8,800
21	1,500	450	300	36	44	38	P	Meotic	Pli	S, Ss	12	30	Af	21	Meotic	7,300
22	2,700	2,000	1,300	37	65	39	P	Meotic	Pli	S, Ss	12	20	Af	7	Helvetian	7,900
23	2,000	500	500	32	48	35	P	Meotic	Pli	S, Ss	15	30	SA	15	Meotic	7,400
24	2,100	1,200	1,000	34	66	37	P	Meotic	Pli	S, Ss	15	90	Af	90	Meotic	9,100
25	1,400	900	750	31	35	34	P	Meotic	Pli	S, Ss	15	110	A	19	Meotic	5,800
26	1,600					34	P	Meotic	Pli	S, Ss	10	20	A	6	Meotic	11,000
27						33	P	Meotic	Pli	S, Ss	10	15	SA	8	Meotic	7,900
28						34	P	Meotic	Pli	S, Ss	10	15	A		Meotic	2,400
29						38	P	Meotic	Pli	S, Ss	15	40	A	6	Meotic	1,200
30						38	P	Meotic	Pli	S, Ss	15	80	A	24	Sarmatian	3,300
31						43	P	Oligocene	Paleog	S, Ss	10	30	AF	22	Burdigalian	3,050
32						43	P	Oligocene	Paleog	S, Ss	10	30	AF	8	Oligocene	1,500
33				42	44	43	M	Meotic, Oligocene, Eocene	Pli, Paleog	S, Ss	12	40	AF	6	Oligocene	3,500
34						44	P	Oligocene	Paleog	S, Ss	10	10	AF	15	Senonian	2,400
35						43	P	Helvetian	Mio	S, Ss	10	60	AF	20	Burdigalian	4,000
36	750	450	450					Sarmatian	Mio	S, Ss			D		Mediterranean	6,500
37														889		

[d] Footnotes to column heads and explanation of symbols are given on page 240.
[3] P, paraffin; M, mixed.

Of the three wells previously drilled to the Meotic on the axis, two resulted in dry gas and the third in salt water.

Tintea has continued to expand in the deep Meotic sand, and indications now are that it will become a field of major importance.

No major discoveries were made during 1938. The most important, however, would appear to be at Draganeasa and the well now testing at Magurele, but it does not seem likely that major fields will be developed in either area.

The results of the 1938 exploratory drilling are rather disappointing. Ten wildcats drilled in areas of known structure led to only two minor discoveries.

The Ploesti and Bacau regions, within which Rumanian development has been concentrated, show little prospect of any appreciable extension. It is believed that other regions in Rumania will have to be explored in order to find additional large fields, and before the long and expensive search for this oil can be commenced, it is necessary that there be State land grants under conditions where the profit possibilities will justify the risks involved. Toward this end, the mining laws are being revised and are expected to come into force during the early part of 1939. At the request of the State, the oil companies submitted their recommenda-

TABLE 2.—*Summary of Drilling Operations in Rumania*

Important Wildcats Drilled in 1938

	Field	Location: Sec. / District	Location: Twp. / Well No.	Total Depth, Ft.	Surface Formation
	Wells Drilling on Jan. 1, 1938, and Completed during 1938				
1	Podenii Noi	Prahova	1,806	9,764	Levantine
2	Berzunt	Bacau	1	3,662	Helvetian
	Wells Started Drilling and Completed during 1938				
3	Draganeasa	Prahova	400	4,774	Helvetian
4	Magurele	Prahova	1	8,439	Buglovian
5	Podenii Vechi	Prahova	2	3,960	Levantine
6	Podenii Vechi	Prahova	1	5,866	Levantine
7	Filipesti North	Prahova	300	5,998	Levantine
8	Manesti	Prahova	2	7,110	Levantine
9	Runcu	Prahova	1	7,743	Levantine
10	Horodnic	Radauti	1	4,013	Miocene
	Wells Drilling on Dec. 31, 1938				
11	Margineni	Prahova	1	7,881	Levantine
12	Orlea	Prahova	351	+5,007	Levantine
13	Surani	Prahova	1	+3,600	Meotic
14	Tetcani	Bacau	1	+3,600	Helvetian
15	Berca	Buzau	1	+1,900	Pliocene

tions for revision of the present mining law, and a commendable spirit of cooperation among the companies and between the companies and the State has been shown.

During the year, several notable steps toward cooperation between the companies were observed through conservation agreements and the formation of unit areas of pooling. Among these, may be mentioned Ceptura north flank and Tintea proration agreements and the exploration agreement in the Malaesti area, but the most important is the Tintea-Liliesti pooling agreement, since it paves the way for further unit areas of this type and will do much toward eliminating wasteful competitive operations and result in greatly conserving the country's resources.

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
	Wells Drilling on Jan 1, 1938, and Completed during 1938							
1	Meotic	Steaua Romana						Drilling abandoned
2	Helvetian	Steaua Romana						Dry
	Wells Started Drilling and Completed during 1938							
3	Helvetian	Astra-Romana-Sospiro......	450		9/32	1,400	1,300	Productive
4	Meotic, Burdigalian	Credit Minier-Neo Petrol	300	0.1	3/16	1,200	900	Productive in Meotic
5	Meotic, Burdigalian	Unirea-Neo Petrol						Drilling abandoned
6	Meotic, Burdigalian	Unirea-Cometa						Dry
7	Meotic, Helvetian	Astra Romana-Sospiro						Dry
8	Meotic	Steaua Romana						Dry
9	Meotic	Unirea-Sondajul						Dry
10	Cretaceous	Concordia						Dry
	Wells Drilling on Dec. 31, 1938							
11	Meotic, Helvetian	Romano Americana-Sospiro						Drilling
12	Pontic	Credit Minier						Drilling
13	Oligocene	Romano Americana						Drilling
14	Burdigalian	Romano Americana						Drilling
15	Pliocene	Astra Romana						Drilling

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1938..................................	24	5
Number of oil wells completed during 1938..............................	156	2
Number of gas wells completed during 1938..............................	3	
Number of dry holes completed during 1938..............................	10	8
Number of wells in which drilling was abandoned........................	10	

Russian Oil Industry in 1938

By Basil B. Zavoico,* Member A.I.M.E.

(New York Meeting, February, 1939)

During 1938 the Russian oil industry, while able to increase its production 4.69 per cent above the preceding year, was not successful in correcting some of its basic difficulties, and the industry's position as it entered 1939 was unsatisfactory. The internal political difficulties of 1937 and 1938 took a toll in the oil industry as they did elsewhere in the U. S. S. R., further complicating the solution of the problems facing it, most important of which still remain: lack of experienced and responsible leadership, able to make quick decisions; undisciplined and migratory labor; and insufficient and often unsatisfactory quality of the various equipment needed by the industry and its ineffective distribution. Recent developments in the U. S. S. R. suggest that during 1939 the management will be granted more latitude and hence somewhat better results may be anticipated from the executive branch, provided, however, the "purges" do not recur. The labor should be better disciplined and should not shift as easily, owing to the introduction, at the close of 1938, of individual labor passports to all workers in the country, the principal purpose of which is to correct those two deficiencies. It is not anticipated, however, that the service of supply will show any appreciable improvement in 1939, partly because of inherent difficulties and partly because the manufacturers of heavy machinery are working primarily and necessarily for munitions.

Production

Production of crude oil during 1938 is estimated at 224,714,000 bbl., as compared with 212,742,000 bbl. in 1937, an increase of 4.69 per cent but 12.76 per cent below the planned output. While there were no major readjustments in the source of supply of crude oil, both the older districts, Baku and Grozny, were barely able to maintain their 1937 levels of production, the increased output being supplied primarily by the fields of Maikop and Ural Permian Basin districts. While exploration work was outstandingly successful in 1937, in 1938 no discoveries of any

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consequence were made, owing almost entirely to the breakdown of drilling operations in the wildcat areas.

The results of drilling operations fell behind the footage drilled in 1937, fulfilling in exploitation work only about 70 per cent of the plan and in exploration work about 30 per cent of the plan. Inasmuch as the percentage fulfillment of the plan is measured by footage drilled, the actual fulfillment of the exploration program was far below the 30 per cent figure, since most of the drilling actually done has been in the shallow portions of the wildcat wells.

The fields of the Apsheron Peninsula (Baku district) were able to just maintain their 1937 rate of production in 1938, producing 164,692,000 bbl. as compared with 164,250,000 bbl. during 1937. As usual, the dependence upon natural flowing production and the neglect of small pumping wells caused the total output to fall considerably below the plan. Such dependence of local management upon the natural flowing production is a considerable handicap both to the country and to the industry because such handling of oil fields constitutes a major waste of the lifting energy and hence of the reserve, and also renders effective planning impossible because the prevailing rates of rapid production of flush reservoirs with resulting precipitate declines and quick water encroachment make even short-term projections of production hazardous. This situation was well illustrated early in 1938, when the rapid development of certain flush areas in Baku district caused the district as a whole to fulfill the plan, but by the second half of the year a 20 per cent decline in the flowing production showed an unanticipated underproduction. In the individual fields of the Apsheron Peninsula, there were no developments of particular importance during 1938. New drilling has been concentrated on the deepest known pre-Kirmaku sands of the "Productive Oil Measures," the deepest oil well in the U. S. S. R. having been completed in July 1938 with a total depth of 10,640 feet.

In the Grozny area of North Caucasus, the results during 1938 were unsatisfactory, the district producing 17,612,000 bbl. in 1938 as compared with 20,800,000 bbl. in 1937. The greatest waste was in the new Gorski field, where the gas-oil ratio is high. This field was rapidly developed during the second quarter of the year, and production reached as high as 150 per cent of the plan under practically criminal exploitation of gushers flowing wide open with large waste of natural gas; so that by the third quarter of the year the field was producing but 40 per cent of the plan. While no detailed information is available, it is apparent that a number of wells were either allowed to blow into oil from the gas-cap area or were producing from both oil and gas zones simultaneously, with resulting waste of gas, natural gasoline and reservoir energy. At the same time, in the Grozny city industrial and refining area, only 40 miles from the oil fields, refineries and plants have been consuming some 7200 bbl. of fuel

oil per day instead of using the available gas, which is equivalent to a waste of some 2,628,000 bbl. of oil for the year.

Most satisfactory results were achieved in the Maikop-Kuban district of the northwest Caucasus, where production reached 13,500,000 bbl. in 1938 as compared with about 10,000,000 bbl. produced in 1937. Also, appreciable increase in production was recorded in the Ural Permian Basin between the Volga River and the Ural Mountains, this area producing about 14,450,000 bbl. in 1938 as compared with 9,700,000 bbl. in 1937. This area is being developed most actively into a primary producing and refining base for the U. S. S. R. because of its strategic value in case of an international conflict. Elsewhere in the country, production remained without appreciable change because of the slow development, and because newer fields that could have produced more oil in Emba, Turkmen, Central Asia and Aliat districts did not have sufficient pipeline facilities to take care of the increased output, while developments on the Sakhalin Island, in the Pacific Ocean, have been retarded for several years because of strategic considerations.

The prevailing practice of remuneration of management and labor for quantitative production without sufficient check either as to quantity or quality resulted last year, according to the Soviet press, in many so-called records achieved only on paper. These excesses were noted in the field of production with certain areas periodically reporting padded figures in the order of 30,000 to 50,000 bbl. per month, while various equipment supplied by heavy industries and machine shops was often not up to specifications and some was actually unusable. Under the somewhat strained internal political situation in the country during 1938, the attempts of the Government to correct the indicated excesses by appointment of inspectors in an endless chain resulted during the year, it is believed, in an idle inspecting superstructure with definitely destructive rather than constructive influence.

Refining

During 1938 Russian refineries ran to stills about 195,000,000 bbl. of crude oil—about the same volume as in 1937. The refining industry was greatly handicapped by the delays in the construction of new plants, several of which, however, are due to start operating early in 1939 With the increasing domestic demand without a corresponding increase in refining capacity in the country, the exports from the U. S. S. R. have greatly declined during 1938, the figures available for the first nine months of the year suggesting a 50 per cent reduction below the exports of 1937. Considering the ever growing demand from domestic sources, complete cessation of exports from Russia is almost unavoidable in the next two to four years unless production and processing greatly increase.

Prospects for 1939

In summarizing the prospects of the Russian oil industry for 1939, it is believed that during the coming year it will be just about able to maintain the rate of production reached in 1938 and that the anticipated declines in Baku and Grozny areas will be compensated by the increased production in Maikop-Kuban district and in the Ural Permian Basin. Production of gasoline in 1939, however, should show appreciable increase and should be of better quality because of the improvement in cracking practices, and also because of the starting of operations in several modern plants whose completion has been delayed. If the internal political situation in the U. S. S. R. reaches some equilibrium this year, it is anticipated that about two years of concentrated effort will be required before large advances in production and refining of crude oil can be realized, to catch up with the rapidly growing domestic and export requirements. In the meanwhile both 1939 and 1940 quantitative results should be comparable to those of 1938. It is obvious that as long as the management forces its new flush fields at peak loads, causing huge waste in reserves and an unpredictable volume of production, no true improvement or effective planning can be achieved. Certainly some measure of proration of flush fields to prevent physical waste and assure steady rate of output is an immediate economic necessity in the U. S. S. R., and without it not much progress can be made. Introduction of proration is dependent upon ample new discoveries and their development and hence radical betterment and acceleration of drilling operations must precede any major improvement in the economy of the oil industry in the U. S. S. R.

Oil and Gas in Trinidad during 1938

By P. E. T. O'Connor*

(New York Meeting, February, 1939)

Production of petroleum in Trinidad during 1938 reached the record figure of 17,737,061 bbl., an increase of approximately two and a quarter million barrels over 1937.

The principal development during the year was along the Guapo fault, which extends from Point Ligoure to Coora across the southwest portion of the island. This fault has been proved to be a major factor governing oil accumulation in the area. At the southeast end of the fault the Coora field has been actively developed during the year and already ranks as one of the major productive fields of the island. Approximately seven miles to the northwest, another richly productive area has been developed on the north side of the fault at Los Bajos, while several widely spaced wells along the fault in the intervening area suggest that the whole seven miles betwen Los Bajos and Coora will prove productive.

The Penal field was placed on regular production during the early part of the year on completion of a pipe line to the Point Fortin refinery. This is a shallow pumping field with a daily output of 2000 to 1500 bbl. of heavy oil.

Down-flank extension of the oil-producing structures of Forest Reserve, Kern and Point Fortin have considerably extended the proven acreages on these structures and exploitation of the deeper Cruse sands on these structures has also materially increased the known reserves.

Wildcat drilling has been active in several areas. Four wells have been completed in the Mayaro district; four at Moruga; six at Cedros; six in the Morne Diable area; one at Erin and one at Point Ligoure. Few data are available from these areas, but it is understood that some encouraging results have been obtained.

In the northern basin, north of the Central Range, two locations were spudded in at the end of the year after extensive seismograph surveys. Both these locations are scheduled for depths in excess of 10,000 ft. This northern basin is entirely untested by the drill and the present drilling program is being keenly followed by all operators in Trinidad.

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Drilling technique and equipment in Trinidad are kept well abreast of the most modern developments in the United States. Unitary draw-works are practically standard on the island and steam pressures are usually 225 lb. per sq. in. Several of the latest heavy-duty Diesel drilling units have been introduced and two of these units are being used on the deep tests in the northern basin.

Excessively high gas pressures at shallow depths still present one of the major drilling problems in Trinidad, necessitating mud weights of 120 to 130 lb. per cu. ft. The native clays of the oil-producing areas make an excellent drilling mud to which barite is added as a weighting material.

Very little mechanical coring is done, as operators rely almost entirely on the electrical survey logs for both completion programs and correlation purposes. Several of the services that are available in the United States are now at the disposal of operators in Trinidad, including electrical logging, gun perforating, deviation surveys, dip-measurement surveys, location of water by electrical survey methods, cementing service.

Production Methods

Loose unconsolidated sands present the major problem in producing Trinidad wells. In the initial flowing stages wells are chocked with from $\frac{5}{32}$ to $\frac{8}{32}$-in. beans to hold back sand and under these circumstances initial productions of more than 500 bbl. a day are rare. Even under this rigid bean control decline rates are rapid. Sand continues to present a problem even in the later pumping stages of a well, necessitating frequent cleanouts and pump replacements. Fine-screen liners have not been universally useful, owing to the fineness of the sands, but recently some operators have been successful in using fine-gauge wire-wrapped screen liners.

No new refineries have been established during the year but extensive additions are being carried out at both Pointe-a-Pierre and Point Fortin refineries by Trinidad Leaseholds and United British Oilfields, respectively.

Summary

The total oil production in Trinidad to end of 1938 has been 162,818,403 bbl. Oil production during 1937 was 15,502,989 bbl. and in 1938 it was 17,737,061 bbl. Average daily oil production during November 1938 was 50,116 bbl. Total gas production during 1938 was 18,500 million cu. ft.

To the end of 1938, 2641 wells were completed and during 1938 the number was 231. Forty-one wells were abandoned during 1938 and at the end of the year 1304 were producing and 850 had been temporarily shut down.

The gravity of the oil was 47° to 14° Bé. and the base was asphalt. The producing formations were fine-grained unconsolidated sands—the Morne L'Enfer, Forest and Cruse in the Miocene, on anticlines and faulted anticlines.

At the end of 1938 there were 428 flowing wells, 516 pumping, 81 on gas lift, 123 on plunger lift, and 156 being produced by other methods.

Petroleum Development in Venezuela during 1938

By Joseph A. Holmes,* Member A.I.M.E.

Although Venezuelan production attained a new peak in 1938, passing the 190 million barrel mark for the first time, there was a distinct flattening of the steep upward trend that marked 1937 and preceding years. The annual total of 190,231,780 bbl. was only 3⅓ million barrels above the 1937 figure, an increase of slightly less than 2 per cent, which contrasts sharply with the 20 per cent increase of 1937 over 1936.

As in the previous year, the Lake Maracaibo fields supplied approximately 73 per cent of the oil produced, Lagunillas remaining the largest single contributor in spite of a 17 million barrel decrease in its annual output. Tia Juana increased its percentage of the Venezuelan total from 14.1 per cent in 1937 to 23.4 per cent in 1938; La Rosa showed little change with 13.7 per cent; Quiriquire in eastern Venezuela was also little changed with 13.2 per cent; Mene Grande, the only other field of real importance, declined from 7.7 per cent of the total in 1937 to 6.6 per cent for 1938.

Two new fields, Temblador and Bachaquero, began actively to ship oil during the year, and by November were averaging 7600 and 10,000 bbl. per day, respectively. The former is in eastern Venezuela, and the latter is the most southern of the proven Lake Maracaibo fields. (A map of Venezuela was published in Volume 127 of the Transactions.)

Table 1 gives a complete résumé of Venezuelan production by fields for 1937 and 1938, and shows that 1,685,575,663 bbl. had been produced to Dec. 31, 1938. The percentage contributed by each of the principal fields to this total is shown in Table 3, as well as their trends over the past several years. From these data it is apparent that the Maracaibo Basin is the principal source of Venezuelan production, and will probably continue to hold this position for some years.

At the year's end 2657 oil wells were producing, of which 2425 were in western and 232 in eastern Venezuela; 36 per cent were on natural flow, 57 per cent were pumping, and 7 per cent were on air or gas lift.

Out of 523 wells drilled, 507 producers were completed in 1938, five less than in the previous year and nearly 100 less than in 1929. These

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* Standard Oil Company of Venezuela, Caracas, Venezuela.

TABLE 1.—*Oil and Gas Production in Venezuela for* 1938

Line Number	Field	Age, Years to End of 1938	Area Proved, Acres			Total Oil Production, Bbl.				Total Gas Production, Millions Cu. Ft.	
			Oil	Oil and Gas	Total	To End of 1938	During 1937	During 1938	Daily Average during Nov. 1938	To End of 1938	During 1937
1	La Rosa	22	26,695	3,533	30,228	341,100,220	24,939,905	26,152,428	66,613	x	25,734
2	Tia Juana	11	15,881		15,881	70,259,862	26,450,509	43,699,980	136,493	x	x
3	Lagunillas	13	42,649		42,649	820,294,220	84,701,427	67,077,121	185,022	x	49,336
4	Bachaquero	9	14,354		14,354	1,058,901	28,532	986,794	10,039	x	x
5	Total Lake Fields		99,579		103,112	1,232,713,203	136,120,373	137,916,323	398,167	x	x
6	Cumarebo	8	1,000		1,000	21,855,086	2,573,712	2,380,482	7,122	11,926	1,518
7	El Mene	16		1,040	1,040	21,046,390	538,734	452,629	1,083	x	196
8	El Mene de Acosta	12	310		310	851,817	7,335			x	x
9	Guanoco	25	150		150	1,855,805				x	x
10	Hombre Pintado	10	x	x	x	344,640	35,195	134,035	383	247	33
11	La Concepcion	14	1,200		1,200	20,208,132	1,069,018	961,017	2,432	x	x
12	La Pas	14	350		350	4,769,370	337,653	861,442	1,811	x	x
13	Las Palmas	10	50		50	246,652	1,063	62,827	240	x	x
14	Los Manueles	9	450		450	16,272,378	1,104,109	1,342,664	4,610	x	1,077
15	Media	8	45		45	2,505,190	160,880	78,378	135	5,047.5	597
16	Mene Grande	25	6,428	172	6,600	198,017,705	14,409,541	12,506,021	31,991	x	10,805
17	Netick	6	154		154	55,118				x	
18	Oficina	2	x		x	194,994	20,017	174,977	1,106	x	x
19	Orocual	5	2,000		2,000	29,528				x	
20	Pedernales	3	1,000		1,000	3,477,291	1,354,487	1,914,548	5,992	2,664	940
21	Quiriquire	9	9,700		9,700	123,995,890	25,877,944	25,208,272	66,634	31,881	7,280
22	Rio de Oro	23	390		390	50,827				x	
23	Rio Tarra	9	900		900	34,279,807	3,143,261	3,894,392	15,794	x	445
24	Temblador	2	5,000		5,000	2,358,793	63,650	2,295,143	7,591	983	13
25	Totumo	23	300		300	149,452				x	
26	Uracoa	2	1,400		1,400	23,701	16,741	6,960		3	1
27	Urumaco	11	100		100	235,989				x	x
28	Wildcat Fields (Amana, Areo, Jusepin, Merey, Santa Ana, Tigre)					78,050	36,380	41,670		x	x
29	Grand Total		130,506	4,745	135,251	1,685,615,808	186,870,093	190,231,780	545,091		

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft. — During 1938	Total Gas Production, Millions Cu. Ft. — Maximum Daily during 1938	Number of Oil and/or Gas Wells — Completed to End of 1938	Number of Oil and/or Gas Wells — During 1938 — Completed	Number of Oil and/or Gas Wells — During 1938 — Abandoned	Number of Oil and/or Gas Wells — At End of 1938 — Temporarily Shut Down	At End of 1938 — Producing Oil Only	At End of 1938 — Producing Oil and Gas[b]	At End of 1938 — Producing Gas only	At End of 1938 — Total Producing	Depth, Average in Feet — Bottoms of Productive Wells	Depth, Average in Feet — To Top of Productive Zone	Oil Production Methods at End of 1938 — Number of Wells — Flowing	Number of Wells — Pumping	Number of Wells — Gas Lift	Number of Wells — Air Lift	Injection into Reservoir[1]	Pressure, Lb. per Sq. In.[d] — Initial	Pressure — Average at End of 1937	Pressure — Average at End of 1938
1	28,467	88.0	1,213	46	20	376	605	162	1	768	1,000–2,800	800–2,600	175	514	79	0	G.25	e1,5xx	e7xx	e6xx
2	x	x	439	171		55	383			383	1,900–2,850	1,600–3,065	252	131				e1,2xx	e1,0xx	e1,0xx
3	43,172	164.3	1,168	97	3	311	828			828	2,270–4,400	2,100–4,900	192	597	39			e1,5xx	e1,1xx	e1,1xx
4	x	2.3	33	26		12	17			17	3,150–5,152	2,850–4,450	17					x	x	x
5	x		2,853	340	23	754	1,833	162	1	1,996			636	1,242	118					
6	1,444	4.5	102	8		21	54		3	57	650–1,500	600–1,400	41	10	3		G.4	625	569	567
7	176	0.75	210			79		80		80	1,050	1,000		40		40		400–500	Vac.	Vac.
8	x	x	27								750	730						x	x	x
9	x	x	15								1,300	1,2xx						x	x	x
10	142	1.1	11	7	1	6	5		1	6		y		5				150	0	0
11	x	x	102			36	65			65	950–3,800	200–2,800	2	63				x	x	x
12	x	x	35			10	23			23	500–2,200	400–1,400		23				x	x	x
13	x	x	7			2	1			1	2,750		2					x	x	x
14	1,172	3.0	19	3		5	11			11	3,550–4,300	3,475–4,150	11					x	x	x
15	273	1.5	20			12		6	2	8	3,000	2,800	3		3		A1	700	50	30
16	9,041	34.7	367	51		213	120	14		134	440–5,000	400–4,500	51	58	25			x	x	x
17			2			2					6,097	5,860						x	x	x
18	x	x	4	2	0	3	1			1	y	y	1					y	y	y
19			3			3					3,000	2,700								
20	1,495	8.4	13	4		6	7			7	6,000	5,000	7					e3,200	e2,37x	2,2xx
21	9,420	31.5	267	41		59	195			195	3,000	2,000	161	34			G3	e1,260	e1,169	1,16x
22			4			3					1,627	1,352						x	x	x
23	720	2.6	90	9		36	44			44	800–4,500	y	7	37				x	x	x
24	970	6.7	51	39		22	29			29	4,000	3,800	29					e1,665	e1,665	1,6xx
25			10			8					2,360	2,2xx						x	x	x
26	2	0.4	1			1					4,350	4,200						x	x	x
27	x	x	4								3,385	3,3xx						x	x	x
28	x	x	6	3		3														
29			4,223	507	24	1,286	2,388	262	7	2,657			951	1,512	149	40	A-1 G-7			

[d] Footnotes to column heads and explanation of symbols are given on page 240.
[1] A, air; G, gas.

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1938: Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulphur, Per Cent	Base[2]	Character of Gas, Approx. Average during 1938: B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Producing Formation: Name	Age	Character	Porosity	Net Thickness, Average in Feet	Structure	Number of Dry and/or Near-dry Holes to End of 1938	Deepest Zone Tested to End of 1938: Name	Depth of Hole, Ft.
1	30.2	12.0	23.8	2.x	A	1,1xx	0.9x	Lagunillas, La Rosa Intermediate and Santa Barbara	Mio-Olig Eoc	SS, H	Por	55–370	M fUL	39	Eocene	5,714
2	28.5	10.0	15.5	2.x	A	7xx	0.6x	Lagunillas, La Rosa, Eocene	Mio, Eoc	SS-S	Por	100–380	MfU	3	Eocene	3,778
3	27	10.5	16.8	3.x	A	9xx	0.4x	Bachaquero, Laguna Lagunillas, La Rosa Eocene	Mio, Eoc	H SS-H	Por	80–950	MfU	3	Eocene	5,399
4	17.3	13.0	15	2.7x	A	x	x	Bachaquero and lower La Rosa series	Mio	Ss-H	Por	75–450	M fU		Younger Tertiary	4,640
5																
6	50.6	48.8	49.8	0.1	P	1,675	6.4	Damsite and Socorro	Mio	Sh	Por	50	AF	12	Miocene	7,720
7	33	32	32.6	tr.	P	y	6.5	Agua Clara	Olig	SH	Por	50	A	74	Eocene	5,576
8	50	41	45	x	P	x	x	El Mene Series	Olig, Mio	S	Por	36	M	82	Eocene	4,994
9	x	x	10.5	x	A	x	x	Guanoco shale	Cre	H	Fis	x	AF	9	Upper Cretaceous	y
10	27.8	18	27.4	tr.	M	y	0.67	Agua Clara	Olig	SH	Por	y	AF	4	Eocene	4,614
11	40.0	27.5	35.5	x	P	x	x	Ramillete Punta Gorda	Eoc	Ss, H	Por	200	AF	1	Punta Gorda	3,800
12	28.5	14.5	20.5	x	A	x	x	La Paz series	Eoc	S, LS	Por	125	AF	4	La Paz series	2,300
13	34.1	29.7	32	y	M	x	x	Patiecitos Formation	Olig	S	Por	y	AF	6	Eocene	5,xxx
14	35.0	27.0	31.0	x	M	x	x	Sandy Shale and Mirador	Eoc	H, SH	Por	400	A	2	Mirador	5,100
15	34	33	33.5	y	P	y	4.0	Agua Clara	Olig	S, H	Por	200	MF	18	Eocene	5,285
16	30.0	14.5	20.5	x	A	x	1.2	Misoa Trujillo, Younger Tertiary Pauji Shale	Mio, Eoc	Ss H, S	Por	800	AF	5	Misoa Trujillo	5,000
17	x	x	26.8	x	A	x	x	Eocene	Eoc	S	Por	y	Af		Eocene	6,097
18	40	20	y	y	M	y	y	Oficina formation	y	y	Por	y	y	0	y	y
19	13.6	13.2	13.4	x	A	x	x	Orocual formation	Plio	Ss	Por	150	MULC	4	Mio-Olig	5,021
20	21.2	21	21.1	3.x	A	1,192	1.68	Pedernales sand	Mio	Ss	Por	500	Af	6	Mio	7,853
21	19	18.4	18.7	1.1	A	777		Quiriquire formation	Plio	Ss Gravel Boulder	Por	500–800	MULC	11	Mio-Olig	8,285
22								Third coal horizon	Eoc	S	Por	60	A		Third Coal Horizon	3,105
23	33.0	24.0	28.0	x	M	x	x	Cubo sands, Mirador and Third Coal Horizon	Eoc	S, SH	Por	800	AF	10	Uppermost Cretaceous	5,080
24	23.1	21.4	22.5	0.8	A	931	0.83	Oficina formation	Mio	Ss	Por	60	MF	9	Mio-Olig	5,296
25	y	y	21	x	A	x	x	Totumo Horizon	Pre-Mio	Breccign	Fis	x	MF	2	Pre-Mio	2,4xx
26	14.9	14.9	14.9	1.4	A	x	x	Oficina formation	Mio	SS	Por	60	MF	1	Mio-Olig	5,061
27	38	37	37.5	x	P	x	x	Urumaco and Socorro	Mio	Ss	Por	y	A	2	Mio	y
28																
29																

[2] P, paraffin; A, asphalt; M, mixed.

wells, as shown in Table 2, include oil discoveries in three wildcats and a major stepout, six gas wells in proven fields, and 16 dry holes.

Development in Proven Fields

Western Venezuela

Activity in western Venezuela was greatest for the second consecutive year in the Tia Juana field, although to a somewhat lesser degree than in 1937; 171 producers were completed in 1938 as compared to 241 in the previous year, and proven acreage in this field was more than doubled. Interesting developments during the year were extensions of light-oil areas in the Lake and the development of Eocene production in a concession nearer shore. Gathering and terminal facilities were completed to handle the greatly increased output of this new field, which averaged 136,493 bbl. per day in November 1938. The three operating companies are Lago Petroleum Corporation, Mene Grande Oil Co., and Venezuelan Oil Concessions, Ltd.

Second in activity was the Lagunillas field, where 97 producers were completed, largely filling in between earlier lakeward and on-shore stepout wells. During the latter half of the year, however, development drilling was begun by one operator on two shallow-water, shoreline concessions that had been idle for some years, and at the year end eight rigs were being operated in this competitive southern extension by the three companies mentioned above.

The Bachaquero field had also been practically inactive since its discovery 9 years ago, although some eight producers had been drilled in the interim to determine production possibilities. During 1938, how-

Table 2.—*Summary of Drilling Operations in Venezuela*

Important Wildcats Drilled in 1938

	State	Coordinates			Total Depth, Ft.	Surface Formation
		North	East	Reference Point		
1	Anzoategui	144,550	520,815	Barcelona Church is N. 300,000 E. 500,000	5,532	Mesa
2	Anzoategui	173,223	595,421		7,815	Mesa
3	Anzoategui	152,361	577,874		6,039	Mesa
4	Anzoategui	91,929	442,122		2,821	Mesa
5	Monagas	119,171	170,752	Maturin Mon. is N. 200,000 E. 200,000	5,042	Mesa
6	Monagas	202,961	203,307		4,850	Mesa
7	Monagas	120,042	260,341		5,141	Mesa
8	Monagas					
9	Monagas	109,376	230,896		4,702	Mesa
10	Monagas	141,964	657,118	Barcelona Church	3,686	Mesa
11	Zulia	−69,680	44,621	Maracaibo Cathedral is o-o	6,848	Recent
12	Zulia	−69,641	44,516		4,000	Recent
13	Zulia	3,900	−5,213		4,151	Eocene

ever, active development of noncompetitive shore concessions was begun by the Venezuelan Oil Concessions, Ltd., and 26 new producers were completed. As a result, proven acreage has been considerably increased and is now roughly the same as that of Tia Juana. The field was shipping some 10,000 bbl. per day in November. Gathering and terminal facilities have as yet been installed only by this company.

In the La Rosa area (which includes Ambrosio and Punta Benítez fields), 46 producers were drilled by the three companies in 1938 as compared to 66 in 1937. There was some increase of proven territory. Production increased approximately 5 per cent over the 1937 figure.

The Mene Grande field was the scene of considerably increased drilling activity in 1938. In this, the oldest Venezuelan field, 51 producers were completed during the year, as compared with 17 successful completions in 1937. In spite of this increased drilling program, however, production for the year was 13.2 per cent below that of 1937. Only 134 wells were producing at the end of the year, as compared to 143 on Dec. 31, 1937, some 213 wells being temporarily shut down. A deep test is now drilling in this field.

In the Los Manueles-Rio Tarra area, southwest of Lake Maracaibo, there was increased drilling activity during 1938, and 12 producers were completed, 9 in Rio Tarra and 3 in Los Manueles. This is an increase of

TABLE 2.—(*Continued*)

Important Wildcats Drilled in 1938

	Deepest Horizon Tested	Drilled by	Initial Production per Day		Choke or Bean, Fractions of an Inch	Pressure, Lb. per Sq. In.		Remarks
			Oil, U. S. Bbl.	Gas, Millions Cu. Ft.		Casing	Tubing	
1	Mio, Olig	Standard Oil Co. of Venezuela						Algarrobo No. 1 N.C.
2	Mio, Olig	Mene Grande Oil Co.	1,392	x	½	625	340	Tigre No. 2
3	Mio, Olig	Mene Grande Oil Co.	possible small pumper					Merey No. 2
4		Socony Vacuum Oil Co.						Suata No. 1. Dry
5	Mio, Olig	Standard Oil Co. of Venezuela	750	x	½	470	225	Jusepin No. 1
6	Mio, Olig	Standard Oil Co. of Venezuela						Maturin No. 4. Dry
7	Mio	Standard Oil Co. of Venezuela	386	0.87	3⁄16	.600	495	TH-13 extended Temblador field 5 km. to E.
8								
9	Mio	Standard Oil Co. of Venezuela						T-31, gas abandoned
10	Mio	Venezuela Oil Dev. Co.						Cerro Negro 1, testing
11	y	Venezuela Oil Conc., Ltd.						L.S. 409. Junked
12	Eocene	Venezuela Oil Conc., Ltd.	145	0.08	½–¼	650–1,000	10–280	L.S. 654. Replacement
13	Eocene	Venezuela Oil Conc., Ltd.						Sibucara No.2 . Dry

	In Proven Fields	Wildcats
Number of wells drilling Dec. 31, 1938	35	14
Number of oil wells completed during 1938	497	4
Number of gas wells completed during 1938	6	0
Number of dry holes completed during 1938	12	4

9 completions over 1937. As a result, production increased 24 per cent in the Rio Tarra field, and 22 per cent in Los Manueles, above the previous year's totals. In Table 1 the age of the Tarra field is given as 9 years, this period having elapsed since the completion of the Colon pipe line. Nine additional years of drilling and testing preceded the production phase.

As in the past three years, there were no new completions in the Concepción-La Paz area, and the production of the Concepción field showed a 10 per cent decline for the year, averaging 2432 bbl. per day in November. La Paz production, on the contrary, was greatly increased. This little field produced less than 200,000 bbl. in 1936, nearly doubled that figure in 1937, and totaled over 860,000 bbl. for 1938. The Concepción-La Paz area has been under development for some 14 years, and has produced approximately 25 million barrels in that time.

The El Mene, Media, Hombre Pintado, Las Palmas group of small, light-oil fields maintained about the same total production in 1938 as in 1937. However, the individual fields showed marked change. El Mene declined 16 per cent, no new wells having been drilled in the period. The Media field proper showed even greater change, falling off over 50 per cent from the previous year. Drilling was discontinued in this field in late 1937 and its rigs moved to Hombre Pintado, where they completed seven producers in 1938, and production showed a resultant increase of 74 per cent. The Las Palmas field had been shut down since about 1930, except for occasional periods when it supplied wildcat fuel. This year it was again put on production, and totaled 62,827 bbl. for the period. The group averaged 1841 bbl. per day during November, all of which was pipe-lined via El Mene to the lake terminal near Altagracia.

In the Cumarebo field eight new producers were completed. This new drilling, together with the continued return of produced gas to the various oil-producing horizons, held production decline to only 7.5 per cent for the year. Drilling possibilities in this small, anticlinal field are now almost exhausted, but in eight years of development it has produced nearly 22 million barrels of 50° A.P.I. oil, and is still averaging about 7000 bbl. per day. It affords an outstanding example of the benefits that can be obtained by return of gas to a reservoir when conditions are favorable.

Eastern Venezuela

The Quiriquire field continued to hold first place in eastern Venezuela both in point of production and of producers completed. Production declined about 2.5 per cent from 1937 figures, averaging about 69,000 bbl. per day for the year, and 41 producers were completed. Proven reserves were increased slightly by encountering commercial production in an eastern extension of the lower sands.

TABLE 3.—*Percentage of Total Venezuela Production from Major Fields*

Field	Year 1934	1935	1936	1937	1938	To Date
La Rosa	16.9	14.5	13.7	13.8	13.7	20.2
Tia Juana				14.1	23.4	4.2
Lagunillas	53.1	54.5	55.4	45.2	35.3	48.6
Total lake fields	69.9	69.1	69.1	73.1	72.9	73.2
Mene Grande	11.0	10.4	10.0	7.7	6.6	11.7
Quiriquire	10.1	13.3	14.9	13.	13.2	7.4
Rio Tarra	2.7	2.7	2.2	1.7	2.0	2.0
Cumarebo	2.8	2.0	1.8	1.4	1.3	1.4
Temblador					1.2	0.1
Others	3.5	2.5	1.9	2.1	3.5	4.4

The Temblador field was put on commercial producing status in early 1938 with the completion of the Temblador-Boca de Uracoa 10-in. pipe line, and the loading terminal for shallow-draft tankers at Boca de Uracoa. Shipments from this point are consigned to the deep-water terminal at Güiria, via Caño Manamo. An active drilling campaign resulted in the completion of 39 producers and determined that the productive area consisted of a rather narrow strip some 20 to 30 km. long. Field terminal facilities are being installed.

At Pedernales four producers were completed during the year, using a steam land rig on the Cotorra concession and a Diesel electric drilling barge for the Amacuro marine concession. Proven acreage was considerably increased, and production averaged about 6000 bbl. per day in November. Operating costs are high in this area because of the swampy terrain and the depth of the wells. Initial subsurface pressures are approximately 50 per cent higher than the hydrostatic head, an unusual condition, which complicates drilling and completion procedure. A loading terminal for shallow-draft tankers was completed at Capure during the year, for despatching crude to Güiria.

The Oficina field, while not yet on a shipping basis, was the scene of an active drilling campaign, and at the year-end six rigs were running in this area. A series of possible producing sands has been encountered in some wells, their oil content ranging roughly from 17° to 40° A.P.I. in gravity. Only two producers were completed during 1938, but other wells are testing various portions of the section, prior to completion. The construction of a field terminal at San Tomé is in progress as well as a road to a proposed deep-water terminal near Guanta on the north coast, 100 miles away. Construction of a 16-in. pipe line along this road will be begun in early 1939.

Exploratory Development

Exploratory drilling in western Venezuela was limited largely to stepout wells in the lake area. As already stated, it opened up light-oil extensions to the La Rosa and Tia Juana fields, and resulted in the completion of a small well at Pueblo Viejo between the Lagunillas and Bachaquero fields (see Table 2). A deep test to the Eocene is now being drilled in the Mene Grande field, as well as a wildcat on the Rio Mototan, to the south. A deep well is also being drilled in the Rio Tarra field, to test the Cretaceous. A test drilled at Sibucara, near Maracaibo, was a dry hole.

In eastern Venezuela an extensive wildcatting program is in progress, and resulted in the completion of commercial oil wells at El Tigre and Jusepin, and a small pumper at Merey, as shown in Table 2. A 5-km. extension of the Temblador field was also proved. Other tests are in progress at Santa Ana, El Roble, San Joaquin, Indios and Aceital, as well as at Cerro Negro, which is testing. Failures were recorded at Maturin, Algarrobo and Suata.

Refineries

There was little change in the refinery situation in Venezuela during 1938. However, Caribbean Petroleum Co. is enlarging its San Lorenzo

Table 4.—*Exports of Crude Oil, Venezuela*

Field	Barrels Exported	
	In 1938	In 1937
La Rosa	41,681,487	20,914,111
Tia Juana	25,872,473	24,931,934
Lagunillas	65,136,018	81,376,237
Bachaquero	637,854	
Total Bolivar Coastal Fields	133,327,832	127,222,282
El Mene, Media and Hombre Pintado	551,579	680,203
La Concepcion	844,493	1,034,340
La Paz	793,686	256,021
Mene Grande	7,768,101	10,142,946
Tarra and Los Manueles	5,057,804	4,215,269
Total from Lake Maracaibo	148,343,495	143,551,061
Cumarebo (Central Venezuela)	2,600,567	2,552,097
Pedernales	1,830,276	1,155,547
Quiriquire	24,122,867	23,959,215
Temblador	1,912,304	
Total eastern Venezuela	27,865,447	25,114,762
Grand total, Venezuela	178,809,509	171,217,920

refinery, and Government approval was finally obtained in December for the construction of a new refinery at Caripito by Standard of Venezuela, replacing the present inadequate topping plant. The throughput of the present Lago La Salina refinery was increased slightly during the year.

Exports

Table 4 shows comparative exports from the various shipping fields, for 1937 and 1938. Increased exports from La Rosa, and the opening up of Bachaquero, were offset to some extent by the reduction in shipments from Lagunillas, but resulted in an increase of 6 million barrels in exports from the lake shore fields. In the remaining lake area, marked decreases in the exports of Mene Grande, the El Mene group, and La Concepción were only partly offset by an increase of 800,000 bbl. in shipments from Rio Tarra and Los Manueles. As a result, total Lake Maracaibo exports had a net increase of slightly less than 5 million barrels. Cumarebo and eastern Venezuela exports also increased by over 2½ million barrels, raising the over-all figure for Venezuela by 3 per cent, or 7,591,589 bbl., to a total of 178,809,509 bbl. exported in 1938.

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Estimate of World Oil Reserves

By V. R. Garfias* and R. V. Whetsel,* Members A.I.M.E.

(New York Meeting, February, 1939)

As pointed out in previous studies, estimates of petroleum reserves if they are to be of value must not only presuppose a clear understanding of what is actually meant by reserves but must be subject to constant revision to conform with changes in their component factors. When such estimates are analyzed it must be clear that it is virtually impossible to obtain comparable figures reflecting the same degree of accuracy, to represent the reserves not only in various countries, but at times even of different fields in the same country.

Estimates of reserves in the United States, subject to frequent independent checks, are obviously more reliable than those furnished, for instance, by the Soviet Government, as the latter must be accepted at their face value and are open to the suspicion of being made to conform with predetermined programs of propaganda. Any tabulation of the reserves of all producing countries, therefore, gives a total that is misleading, as the component items are not arrived at on the same basis and therefore are not homogeneous in a true sense.

Only a fraction of the petroleum stored underground, usually associated with natural gas, is or can be brought to the surface, and although practically all the natural gas underground can be recovered, in actual practice in some fields a large part of the gas that reaches the mouth of the well is wasted. It is thus estimated that in the United States only some 25 to 35 per cent of the petroleum underground in proven fields is actually economically recovered. Estimates of reserves, therefore, should make clear the distinction between the known amount of oil underground in producing fields and the portion that actually can be brought to the surface.

It cannot be overemphasized that as a result of the operation of the "Law of Capture," which controls subsoil ownership in the United States on comparatively small landholdings that seldom if ever cover the entire producing area, the oil fields are not as economically exploited as some foreign fields, and that as a result (were it not for the easy accessibility of the domestic market, the largest in the world) some American production would now be unprofitable in open competition with foreign oils.

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The Law of Capture in the United States causes waste not only on account of useless investment by putting a premium on unnecessary wells but also as a result of the harmful dissipation of reservoir energy due to

TABLE 1.—*World Oil Reserves*[a]
MILLIONS OF BARRELS

Country	Reserves on Jan 1, 1939		Production to Jan. 1, 1939	
	State	Country	State	Country
United States		14,000[b]		21,184
Texas	7,500		5,650	
California	2,800		5,162	
Oklahoma	900		4,440	
Louisiana	600		864	
Kansas	600		958	
New Mexico	550		197	
Illinois	280		455	
Wyoming	280		454	
Pennsylvania and New York	200		1,071	
Arkansas	120		460	
Others	170		1,473	
Russia		5,000		4,025
Iran		3,500		878
Venezuela		2,500		1,693
Iraq		2,500		137
Dutch East Indies		1,600		838
Rumania		700		835
Mexico		600		1,895
Colombia		400		230
Argentina		200		187
Peru		200		240
Trinidad		150		164
Others		550		957
				33,263

[a] No attempt is made to classify reserves into *proven, profitable* or *unprofitable*, nor to add these heterogeneous figures.

[b] These figures are lower than the estimates of the American Petroleum Institute, the difference hinging mainly on the estimates of reserves for Texas, and in the personal equation in deciding just what is and what is not proven acreage.

loss of dissolved gas and premature water encroachments, which brings about a reduction in the recoverable oil.

PROVEN AND PROFITABLE RESERVES

The term *Proven Reserves*, although sanctioned by long usage, is somewhat misleading, as *proven* denotes merely *known existence*, and the term

could thus logically be applied to the billions of barrels that unquestionably are *known* to exist in the Athabasca oil sands in Alberta, for instance. The term *proven reserves* is often used in this sense but, unfortunately, it is probably more often used with the implication that the known reserves in question can be *profitably* exploited, and this dual usage gives rise to serious errors.

It should be noted that there are many *known or proven* reserves like the tar sands mentioned above, which it is now *unprofitable* to exploit but that later may become profitable, and others that are now profitable but may become unprofitable at any time; thus changes in the price of crude that do not affect the volume of *known* or *proven* reserves in any one field may drastically increase or decrease its *profitable* reserves.

Classification of Reserves

In line with the foregoing, it is suggested: (1) that the term *proven reserves* be restricted to apply only to *known* reserves without implying whether or not they can be exploited economically, (2) that the term *proven profitable reserves* be used to denote known reserves that can be economically exploited and (3) that the term *proven unprofitable reserves* be used to denote known reserves that cannot be economically exploited.

Proven reserves may be described as the future yield of present producing wells and of wells to be drilled on proven locations; *proven profitable reserves* as the future economic yield of present producing wells and of wells to be drilled in proven locations and *proven unprofitable reserves* as the future though uneconomic yield of said wells. In each case the estimates are to be based on conditions prevailing at the time the estimates are made or varying from same within reasonable range.

There are other oil reserves besides those that can be classed as *proven profitable* and *proven unprofitable*, but their appraisal is largely dependent on the purpose for which estimates are made and their definition is largely based on the personal judgment of the appraiser.

With the foregoing limitations in mind, it is suggested that under *probable* reserves, in a general way, be classed those that are reasonably expected to become *proven profitable* in a given time, and that under *prospective* reserves be grouped those that possibly but not probably may be *proven profitable*.

It should be evident that although no reliable estimates can now be made of the world's *proven profitable* oil reserves, such estimates are not altogether meaningless if interpreted within the narrow limits of their usefulness. It is desired to emphasize that the reserves as listed in the accompanying table are not classified or differentiated as to type, and that they include such heterogeneous items as the largely *proven profitable*

reserves of the United States, and the reserves of Russia, which cannot yet be classified. Obviously these estimates of reserves of different countries are not made on a comparable basis, and the justification for this study so far lies more in bringing this situation to the attention of those interested in petroleum reserves than in the comparable usefulness of the figures themselves.

Chapter V. Refining

Review of Refinery Engineering for 1938

By Walter Miller,* Member A.I.M.E.

Developments in oil refining were so varied during 1938 that a refiner had to be alert or be left behind. The long-talked-of conversion of oil refining into a true chemical industry using petroleum as a raw material was hastened, particularly in the realm of motor-fuel manufacture, by the increased understanding and use of catalytic processes. The petroleum refiner's vocabulary has been extended to include alkylation, cyclization, aromatization, and isomerization. There are other developments of a similar nature, but these are now considered commercially feasible under proper conditions.

New Equipment

Less expensive equipment and processes encouraged new construction and replacement. Estimates of money spent in the United States on building new plants and remodeling existing installations during 1938 place the sum at not less than $200,000,000, a noteworthy amount in a year marked by a business recession.

The commercial application of small-scale catalytic polymerization of refinery gases made one of the latest advances available to the smaller operators, who usually are faced with unit installation and production costs higher than the large refinery enjoys. Competition was thereby fostered. Outstanding in this respect was the construction of two or more polymerization plants in small refineries at extremely low installation costs, with amortization measured in months instead of years.

Houdry Processes

Bursting like a bombshell late in the year was the disclosure of the extent of the development of the Houdry processes of catalytic cracking, viscosity breaking, gasoline treatment, desulphurization, and polymerization, said to be applicable to almost any raw petroleum stock and yielding gasoline of exceptionally high octane number. This process is claimed to be particularly adapted to once-through cracking of aliphatic hydrocarbons, and when combined with any of the conventional thermal

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cracking units for further cracking of recycled material is reported to give greater yields of higher octane motor fuel than is possible with thermal cracking alone. Several installations have been operated by the companies engaged in the development, and announcement was made of the immediately projected expenditure of $35,000,000 for 10 additional units. Other processes of catalytic cracking are under active development and may shortly be commercial.

The situation presages the return of the "octane race" in motor fuels, a phase of competition that has been fairly dormant for a few short years. Marketing by a few refiners of "house brand" grade of motor fuel manufactured by processes not requiring the addition of tetraethyl lead, and having an octane number higher than the 72.3 limit by the L-3 method established by the Ethyl Gasoline Corporation for its licensees a year ago, will force competitors to consider means for supplying equally as high antiknock products to the consuming public. Although the vast majority of motor vehicles in service do not require the high antiknock quality available in even the regular grade of gasoline on the market, most of the newer cars have been and will continue to be designed for the highest octane rating the motor designers can foresee and, as time goes on, the older cars will disappear from the scene. The customer continually gains through the joint efforts of the motor-fuel manufacturer and the motor builder.

Hydrogenation and Treatment of Motor Fuel

Continued increase in the application of hydrogenation to the manufacture of high-octane aviation gasoline, which yielded an estimated 2,000,000 gallons of fighting-grade gasoline in 1938, is expected to provide capacity for 20 times as much of the product in 1939. The military aviation program contemplated for the United States will strain the production capacity of the oil industry and without question will force further expansion of iso-octane manufacture by polymerization and hydrogenation.

Methods for treating motor fuel were improved through refinement of the doctor sweetening process, the newer copper chloride and lead sulphide processes, and by the development of catalytic processes for the removal of sulphur compounds. The low-temperature acid treatment of cracked distillates, also effective as a method for removing organic sulphur compounds with a low treating loss, was expanded greatly through the construction of Stratcold process units by a number of refiners. The problem of gasoline treatment continued to be attacked through another avenue also—the development of more satisfactory inhibitors against deterioration of color, the formation of gums, and other undesirable qualities.

The blending of alcohol produced from farm products with motor fuel continued to receive attention, particularly in light of the extremely low prices received by the farmer for grains. However, reports of a study by the U. S. Bureau of Chemistry and Soils, made before the American Chemical Society at its fall meeting, called the "production of power alcohol as a national movement . . . entirely impractical." Distribution of alcohol blends continued on a small scale.

Lubricating Oil

The trend toward the use of constantly lower proportions of lubricating oil to the volume of gasoline consumed was made sufficiently definite to merit comment. Today the proportion of total lubricating oil consumed as motor oil and industrial lubricant compared to the gasoline consumed is little more than half of the figure for a decade or so ago. This gratifying result is an evidence of the effect of contributions by the scientific engineers and technologists of both the refining and motor-car industry, the cooperative efforts of which have led to improved design of motors and higher quality of lubricants.

Important solvent-treating lubricating-oil installations were made, particularly in California and on the Gulf Coast, bringing available solvent-treatment capacity to considerably more than 60 per cent of the total lubricating-oil production capacity of the United States. Further commercialization of the processes of deasphalting, deresinating, and acid treating in propane solution made possible the commericial utilization of stocks containing large quantities of residual material in the production of high-grade lubricants.

Purification methods involving filtration of lubricants through fuller's earth and other adsorbing mediums were augmented by the introduction of prepared bauxite, the latter offering the advantages of longer life through greater physical stability during handling and the possibility of some improvement in the quality of the filtered lubricating oil.

Problems of engine deposits, "varnish" or lacquerlike incrustation of engine parts, and ring sticking received major attention both from automotive designers and petroleum technologists. These problems have arisen as a result of the higher speed, greater bearing pressures, and closer clearances of moving parts in the modern automotive engines. Diesel engines, operating as they do at considerably higher bearing pressures than gasoline motors, are particularly subject to ring sticking, but this problem is being solved successfully by the development of a combination of carefully selected lubricating oil and addition agents. Some effort is being made to standardize both Diesel engines and fuels to cut down the number of differing fuel specifications now apparently needed.

Burner Distillates

While the rate of installation of domestic oil-burner equipment has slowed down, the use of burner distillates has continually increased. The consumption during the winter of 1938–1939 is expected to be over 72,000,000 bbl., or a 15 per cent increase over the 1937–1938 season.

Petroleum Gases

Utilization of refinery gases in chemical manufacture, and the increasing interest in petroleum as a chemical raw material, were evident from the vast amount of published literature and from the semicommercial development of a plant and process for the production of butadiene either from petroleum gases or from kerosene or gas oil. Although use of specific catalysts for the accomplishment of controlled chemical changes in petroleum hydrocarbons has been publicized during the year, the development work, of course, has been in progress for several years.

The industry was startled also by the announcement of the commercial development of glycerin production from petroleum gases, indicating the great steps that have been made toward the realization of the petroleum chemist's dream of building a chemical industry on the petroleum hydrocarbons similar to the chemical industry that has been developed on the coal-tar hydrocarbons.

Utilization of petroleum gases in the liquefied state continued in increasing volume, and is becoming more important both to the natural-gasoline manufacturer and the refiner. The volume of pure and mixed hydrocarbon gases in liquid form used during the year probably exceeded 4,000,000 barrels.

Mechanical Improvements

In the field of mechanical improvements, the development of a method for removing coke from coke stills by the application of high-pressure water jets excited considerable interest because of the great increase in safety and speed thus provided. Improved cracking-still tube-cleaning methods involving the removal of most of the deposited coke by steam and the oxidation of the remaining carbon under controlled conditions has proved practical and promises increased efficiency in cracking-still operation.

A marked advance in refractory manufacture has resulted in the production of insulating firebrick weighing approximately one-fourth as much as ordinary firebrick and possessing several times the insulating effect. The advantage of the decreased weight in construction is obvious.

Mud Technique in Iran

(Author's reply to discussion that appears on page 21.)

M. W. Strong.—The method of drilling mentioned by Mr. Pollard has been employed by this company, but it is permissible only if no knowledge is required of the formation being drilled. I am not in a position to know whether the stratigraphic knowledge of Bahrein is yet sufficiently exact to employ this technique with safety to the pay.

In reply to Mr. Power, I would say that "heaving shale" troubles in Iran are very different from those on the Gulf Coast. They appear to be associated with extreme thrusting in salty marls. We employ pressure drilling with saturated brine muds. No bentonites have yet been identified in the drilled sequence. An interesting point is that two wells, a little over a mile apart, drilled through 10,000 ft. of the same formation. Extreme formation pressures with heaving or unstable formation were encountered in the one in which extensive overthrusting was present, whereas no difficulties whatever were met with in the other, in which thrusting was negligible.

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(NOTE: In this index the names of authors of papers and discussions and of men referred to are printed in SMALL CAPITALS, and the title of papers in *italics*.)